

VISUAL, ACOUSTIC, AND SEMANTIC ENCODING
IN VISUAL SEARCH

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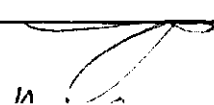
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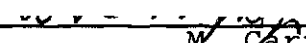
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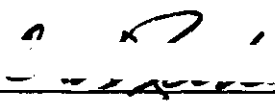
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SUMMARY

When we see a word in print we can respond to it in at least three ways. We can respond to the physical features, i.e., its letters, or we can respond to its acoustic features of the word, i.e., the sound with which it is associated, or we can respond to its semantic features of the word, i.e., its meaning. Five experiments were conducted to investigate how people respond to these three different features of words. Specifically these experiments were conducted to determine why search for semantic features is faster than search for acoustic or visual features. In each experiment subjects were given a clue to a word that they were to find or identify. The clues was either a physical feature (initial letters), an acoustic feature (rhyme), or a semantic feature (category) of the word. Four hypotheses were tested:

- 1) Semantic units of processing are available before acoustic or visual units.
- 2) Context aids search for semantically defined targets.
- 3) Subjects can respond simultaneously to more words when searching for semantic targets.
- 4) Subjects need to determine fewer physical characteristics of the stimulus to make semantic decisions.

Three types of tasks were used in these experiments choice reaction time, search, and tachistoscopic recognition.

The results of Experiment 1 showed that when subjects could respond only to one word at a time, semantic decisions were slower than acoustic decisions, which were slower than visual decisions. The results of Experiments 2 and 3 showed that context did affect search for semantically defined targets. When context was altered by disrupting word order (Experiment 2), search for targets defined semantically was faster than search for targets defined acoustically or visually. Analysis of median search speeds showed a small improvement in search time with normal word order, but only for category targets. In Experiment 3, context was eliminated by having subjects search through random lists of words arranged in paragraph order. Search times for rhyme and category targets did not differ.

The results of Experiment 4 suggested that the size of response units is different in search for rhyme and category targets than in search for letter targets. Subjects were presented five words on each trial and they decided whether any of them fit a given letter, rhyme, or category clue. The results showed that speed of reaction did not differ for targets in the first two or last two positions. These results suggest that subjects may have

been responding to more than one word at a time when searching for rhyme and category targets.

The results of Experiment 5 suggests that more information about the stimulus word is necessary for rhyme decisions than for category decisions. Subjects viewed five stimulus words presented for 500 msec. and tried to identify the target word on the basis of a letter, rhyme, or category clue. Subjects were able to detect category targets more accurately than rhyme targets, and with about the same accuracy as for letter targets.

CHAPTER 1

INTRODUCTION

When we recognize a word in print we are able to respond to that word in at least three ways. First, we can respond to its physical features, i.e. its shape, size, the particular letters present, etc. We can also respond to the word acoustically by pronouncing it either out loud or subvocally. The third way we can respond to the word is by thinking of its meaning, for example, defining the word or giving an example of how it could be used in a sentence. In this paper these three qualitatively different modes of response to words will be referred to as (1) visual or physical feature analysis, (2) acoustic or auditory feature analysis, and (3) semantic analysis. This thesis is concerned with the ways in which people respond to words when reading. Specifically it is concerned with the analysis of these three types of responding as they relate to the understanding of printed text. In studying these three modes of response to words it is important to recognize that these different characteristics of words can be defined in several ways. For example, physical features may take on many forms, e.g. size, shape, or particular letters present. Acoustic features may be defined as

phonemes, syllables, or multiphonemic and multisyllabic units. There are also various types of semantic features including associative relationships and category membership.

These three modes of response to words are interrelated. For example at the level of a single word, we must determine the physical or visual aspects of a printed word before we can determine how to pronounce it or what it means. The degree of physical feature analysis that is necessary for acoustic or semantic analysis is not immediately evident. We do not always need to identify each letter of a word in order to recognize it because letters are often redundant within words. For example, we recognize that the missing letter in "q_ickly" must be "u". We do not need the letter "u" to identify the word. However, the missing letter in "l_ne" could be "a", "i", or "o", so that without the aid of context we cannot accurately identify the word.

Although the degree of physical feature identification necessary for semantic and acoustic feature analysis is not clear, the fact that they are related is clear. For example, acoustic and semantic analysis are linked in the development of reading. By the time a child learns to read, he is presumed to have learned to use the spoken language. While he cannot at first respond to the meaning of printed

words, he learns to do so by learning how to transform the written version to an oral form. Given that the child already knows the meaning of orally presented words, the acoustic response may mediate semantic analysis of visually presented words. This process suggests a link between auditory and semantic analysis.

The effects of differential mode of response on memory for verbal stimuli has been the object of considerable attention in the literature recently. Craik and Lockhart (1972) and Craik and Tulving (1975) suggest that these modes of response represent different levels of processing of the stimuli by the subject. The semantic mode of response is thought to reflect a "deeper" level of processing, and depth is associated with better recall of the stimulus. The concern of this thesis, however, is not with the durability of the stimulus trace after encoding but with the nature of the encoding process itself.

The encoding process is studied by requiring subjects to attend to specific features of words. The experimental tasks that can be used for this purpose include choice reaction time, search reaction time, and tachistoscopic recognition. These three tasks have been used extensively in determining the nature of encoding for physical characteristics of words. When these tasks are used to

compare physical feature analysis with semantic and acoustic feature analysis the results suggest that these types of responding are qualitatively different.

This thesis is concerned with visual, acoustic, and semantic characteristics of individual words. Two lines of evidence suggest, however, that reading is not a word by word process. This may mean either that the word is not the unit of analysis in reading or that people do not attend to each individual word when they read. First, there is evidence that subjects respond in accordance with the redundancy present in printed English, and that they are able to selectively attend to critical features in text which provide the most information. Second, the analysis of eye movements in reading suggests that subjects do not attend to one word at a time when reading. In this introduction these lines of evidence which suggest that reading is not a word by word process will be discussed. This will include a discussion of use redundancy in language and how eye movements can reflect processing while reading. After this there will be a discussion of the techniques used in studying how people respond to the physical features of words. As noted above these include choice reaction time, search reaction time, and tachistoscopic recognition. Then the research in which the techniques used in investigating physical feature analysis are used to compare visual with

acoustic and semantic feature analysis, and some of the questions that arise from this research will be described. Finally the hypotheses that have been put forth to account for the differences noted among visual, acoustic, and semantic analysis will be summarized and evaluated. Five experiments will then be proposed to test these hypotheses.

The Unit of Analysis in Reading

Redundancy in Verbal Material

Redundancy in printed English can take at least two forms. First there is statistical redundancy which refers to the frequency of occurrence of particular features. These features could be letters, words, classes of words, or other linguistic features. For example, the word "the" occurs very often in printed English and thus is very redundant or predictable. Redundancy can also refer to repetition of a particular semantic or syntactic feature. For example, number, i.e. singular or plural, can be marked by a pronoun and by a verb form in the same phrase (e.g. he sings). Statistical redundancy in printed language from several sources including the sequential dependencies among letters within words. For example, in English, "q" can only be followed by "u". "Th" can only be followed by a limited number of possible letters (a, e, i, o, u, r). Certain

combinations of letters can only occur at the beginning of a word while others can only occur at the end of a word (Venesky, 1967; Gibson, 1971). Another source of redundancy can be seen in the information content of words taken as a whole. Miller, Newman, and Friedman (1958) classified English words into two categories according to the amount of information provided by each. They found that in general words could be classified as either function words (e.g. articles, conjunctions) which are highly redundant and carry little information, or content words, such as nouns, verbs, adjectives, numbers, yes, no, which carry most of the information in a passage. Redundancy in language also comes from contextual constraints. Contextual constraints may be determined either semantically or syntactically. Semantic constraints operate to determine which class of words may occur in a given position in a sequence of words in a sentence. Syntactic restraints reflect rules of word order which determine where particular words, which serve certain functions in a sentence (subject, object, predicate), may appear in the sentence. Take for example the phrase:

(1) "The man was on his way to..."

In this example, the sentence will often be completed with a noun phrase which denotes some place. One might complete the phrase in (1) with "the opera" or "the post office". A

noun phrase is necessary because of the syntactic constraints, while the semantic constraints make the reference to some place probable.

It seems reasonable to suspect that skilled reading is dependent on the ability to respond in accordance with the redundant features of printed language. To do this, readers must learn where redundancy exists. Miller (1958) has shown that subjects can learn to use structure or redundancy in learning unfamiliar material. He had subjects learn lists of strings of letters of varying length. Within all of the strings only four letters, x, g, n, and s, were used. Half of the strings were constructed by random selection among the four letters. The other strings were structured in such a way that there were rules of sequential dependency within the stimuli. For example, "n" might only be followed by "x" or "s"; or "g" might only occur at the end of a string. When subjects were required to learn nine-item lists of redundant or random strings, the redundant strings were learned in fewer trials and with fewer errors. These results indicate that subjects can respond in accordance with the redundancy in printed material.

Because subjects can use redundancy in printed material it is important to determine the sources of redundancy in printed English. Newman and Gerstman (1952) indicated that

the most informative, that is, the least redundant, parts of words are the beginnings and ends of words. Little information is carried in the middle parts of words. If this analysis is correct, one would expect subjects to attend more carefully to the initial and final letter positions of words if they are processing the available information most efficiently. Haslerud and Clark (1959) reported that the ends of words, letters in the initial and final position, are perceived better than the middle letters. Bruner and O'Dowd (1958) found that latency to identify a tachistoscopically presented word was greatest when there were typographical errors in the beginning or end of the words as compared to when there were typographical errors in the middle parts of the words. This finding parallels the common experience of missing structural errors in proofreading. In addition to these findings, Horowitz, White, and Atwood (1968) found that the beginning part of a word is the best cue for eliciting recall of that word, while the middle part is the least effective cue for recall.

Rules of sequential letter constraints also serve as a source of statistical redundancy in words. For example, there have been a number of studies which show that letter recognition is superior when letters are embedded in a word than when the letters are presented alone. Reicher (1964) and Thompson and Massaro (1973) showed that subjects

identified a letter which had just been presented tachistoscopically in a word more accurately than when it had just been presented alone. Smith (1969) investigated the effect of intraword redundancy in letter recognition. He had subjects view three letter sequences of words and nonwords which were either high or low in redundancy. The sequences were presented at a below threshold level of illumination and then the level of illumination was gradually increased. Recognition was measured by seeing which level of illumination was necessary for correct identification of the three letter sequence. The highly redundant words (e.g., ant) were recognized best (at the lowest level of illumination). The highly redundant nonwords (sti) were recognized better than the low redundant words (dry) and low redundant nonwords (duv). This result seems to indicate that superior recognition of letters in words is due to redundancy of information rather than to their occurrence in words per se. Lott and Smith (1970) used a similar technique to measure recognition thresholds in children and adults. They found that superior recognition of letters in words compared to letters presented alone occurred in first graders, indicating that children respond in accordance with statistical redundancy at a very early stage.

Evidence that children use redundancy in English also

comes from studies which have looked at the effects of orthographic structure. Orthographic structure refers to the rules which govern permissible letter sequences in words. For example, certain letter combinations can occur only at particular positions in English words. Gibson and her associates (Gibson, Pick, Osser, and Hammond, 1962) manipulated orthographic structure by using nonsense words which were high or low in pronounceability. They presented these nonsense words tachistoscopically and measured the exposure time necessary for correct identification. Nonsense words which were high in pronounceability, that is, they corresponded closely to order of letters in English (e.g. GLURCK is high in pronounceability since GL does occur in initial position and CK does occur in final position in English words) required less presentation time for correct recognition than nonsense words which were low in pronounceability (CKURGL is a corresponding nonsense word which is low in pronounceability since CK does not occur in initial position, and GL does not occur in final position in English). Gibson and her associates (Gibson, Osser, and Pick, 1962) also showed that trigrams high in pronounceability (NAR) were easier to identify (in brief visual presentation) than trigrams which were low in pronounceability (RNA), and that this effect is apparent by third grade. Thus rules of orthography seem to be incorporated very early in the educational process.

Further evidence of the effects of orthographic structure on verbal tasks in young children comes from Kellas and Butterfield (1970). Using a paired associate task they varied pronouncability of response items. Fewer errors were made on items high in pronouncability. This result might indicate that items that correspond more closely to rules of spelling are easier to learn as well as to recognize.

Evidence that people are able to use redundancy from orthographic structure comes from studies using pseudowords which vary in order of approximation to English (or some other language) as described by Miller, Bruner, and Postman (1954). A zero order of approximation pseudoword is obtained by drawing letters at random such that all letters occur with equal frequency until the desired number of letters is obtained. In first order of approximation stimuli, the letters are chosen randomly but the letters occur with the same frequency that they do in English. In constructing second order pseudowords one starts with a two letter sequence, for example, "we" and obtains the next letter by searching through text for the next letter that follows the first occurrence of "we". The next letter is obtained in the same manner with the new two letter sequence formed by "e" and the letter just added. To form third order approximations three letter sequences are used instead of two letter sequences and so forth. Thus, low order of

approximation pseudowords have little correspondence to English rules of spelling while higher order of approximation pseudowords correspond quite closely to English rules of spelling. An example of a fourth order of approximation stimulus is "vernalit". An example of a zero order of approximation stimulus is "dlegqmnw". Miller et. al. found that recognition of tachistoscopically presented pseudowords (as measured by percentage of correct placement of letters) improves as sequences of letters more closely approximate sequences which occur in English. These authors also note, however, that if you consider the statistical redundancy inherent in sequences which closely approximate English, the amount of information actually transmitted was constant over presentation time. That is, while more letters are recognized in a fourth order approximation pseudoword than in a first order approximation pseudoword, the fourth order stimulus is more redundant than the first order stimulus, and the amount of information gained in those letters that are recognized is the same in both cases. This implies that the amount of information that a subject can process in a given amount of time is relatively constant. Subjects are able to incorporate rules which specify permissible strings of letters, and this knowledge leads to more efficient information processing. This process may partially account for the increase in span of recognition which occurs with increased proficiency in

reading as discussed earlier.

That higher order approximation pseudowords are processed more rapidly has been amply demonstrated. For example, Merikle (1969) presented ten letter zero and second order approximation English pseudowords auditorally at rates of 1, 2, and 3 letters per second, and had subjects recall as many letters as possible after each presentation. He found much better recall for the intermediate presentation rate, and no differences between second and zero order stimuli with slow rate of presentation. These results indicate that less time is required to process the more familiar material into memory, probably because there is less informational content in the higher order pseudowords. Mewhort, Merikle, and Brylen (1969) also showed that familiar letter sequences are encoded more rapidly than random letter strings. They presented eight letter sequences of zero and second order pseudowords tachistoscopically and varied presentation time and interstimulus interval before onset of a masking stimulus. Thus they were able to control processing time. For short processing time many more letters were reported accurately from the higher order of approximation stimuli than from the lower order stimuli. This effect diminished as processing time increased, showing that the more familiar sequences were encoded to memory more rapidly. In addition, these

researchers performed a second experiment in which they masked only the left or right four letters of each stimulus. Masking the left side resulted in decreased recall more than masking the right side at short interstimulus intervals. This effect disappeared as the delay of mask increased. The authors conclude from this result that input into memory generally goes from left to right; however, they do not assume that the input must be strictly sequential. As was stated before, the information in English words is generally greatest in the initial positions and least in the middle portions, and that subjects tend to attend more to the informative parts of words.

Eye Movements in Reading

A second line of evidence which suggests that reading is not a word by word process is the analysis of eye movements in reading. An analysis of the eye movements of a typical reader suggests that normally the skilled reader does not fixate every word in a line of print (Haber, 1974). An examination of the pattern of fixations of adult readers, that is the time in which the eyes pause as the eyes move from point to point along a line of print, reveals that they make about four fixations per second. One can identify only about 5 or 6 unrelated letters in the time taken by one fixation, although one can probably notice gross details,

such as extra large spaces at the ends of sentences from peripheral vision. Since good readers can read faster than four words per second, it doesn't seem that they could be fixating on each word in a line of print.

If readers do not see each word clearly, how do they determine the meaning of a passage accurately? The answer would seem to lie in the reader's ability to construct or infer words which he does not actually see clearly. Various types of information can be gained about such words without actually seeing them clearly. For example, readers can make use of information about word shape or word size, and information provided by contextual constraint and redundancy as discussed earlier. The critical process here is the reader's ability to make sense out of partial information by developing some sense of what a particular passage is about. It seems that the reader must be able to form a hypothesis about what is being said in the passage he is reading, and to use partial information gleaned from the text to check and revise this hypothesis as he goes along. This account of the reading process is essentially that given by Haber (1974) and Kolars (1970).

Support for this notion comes from several sources. A further analysis of eye movements indicates that reading speed is gained by making fixations further apart rather

than by making briefer fixations or by moving eyes more rapidly between fixations. Fixations in reading are of a relatively constant duration (although their duration steadily decreases from first to fourth or fifth grade). One would expect from this analysis that fixations occur relatively close together at the beginning of a paragraph or where there is a change in context, and at greater intervals as the context becomes more obvious. In fact this is the case (Haber, 1974). In addition, the pattern of fixations is also dependent on the nature of the material being read, with more familiar material requiring fewer fixations per line than less familiar material (Laycock, 1958). One would also expect that the slow reading speed characteristic of poor readers would be accompanied with an increase in the number of fixations made per line of print. Rubino and Minden (1973) found that poor readers do read twice as slowly and make twice as many fixations per line as good readers.

Support for this account of reading also comes from experiments in which subjects have to make use of partial information in comprehending a passage. Since prose passages contain many words which are redundant, subjects should be able to fill in words which have been deleted from a passage with a fair degree of accuracy. Tuinman and Gray (1972) found that subjects can read passages with a high

degree of comprehension when a large number of words have been deleted from the passage. Chapanis (1954) found that subjects can reconstruct passages with a high degree of accuracy (70% correct replacement) when a substantial number of words (25%) have been randomly deleted from the passage. These findings indicate that subjects can make efficient use of partial information in printed text.

Another source of support for this account comes from experiments which measure the eye-voice span in reading. The eye-voice span is a measure which is made by simultaneously recording the eye movements and voice of a reader as he reads aloud. From this recording, one can determine the lag between the time when a word is fixated and the time when it is uttered by the reader. This lag is the eye-voice span and it is measured either in time (from when a word is fixated to when it is pronounced) or in words (number of words on the page between the print where the eye is fixated and the word which is being simultaneously spoken by the reader).

Variations in the eye-voice span may be taken as a measure of on going short-term processing in reading. In general, this processing should reflect the amount of information that the reader is inferring from contextual constraints (Levin and Kaplan, 1971). The eye-voice span

varies with the meaningfulness of the text, being greater for more structured or constrained material (Morton, 1964). Geyer (1968) found that the eye-voice span is smaller for more difficult texts than for easy material. Levin and Kaplan (1971) report that the eye-voice span increases toward the middle of a passive sentence because the latter part of passive sentences are highly constrained by the former part, and that no such corresponding increase in the eye-voice span occurs toward the middle of an active sentence because the latter part of an active sentence is relatively independent of the former. In addition, they also report that older subjects have longer eye-voice spans than younger ones, and that fast readers have longer eye-voice spans than slower readers. Levin and Kaplan conclude that good readers are able to process more information, in terms of larger units or phrases as reflected by their ability to adapt their eye-voice span to the structure of content of the reading materials.

Another important consideration in the analysis of eye movements in reading is the span of recognition, that is, the amount of material perceived in each fixation. With increased experience in reading, subjects learn to use structural and orthographic information, which is based on form and patterns of letter sequences in the written language, and thus the span of recognition should increase.

This increase may be another source of greater efficiency in reading. Tinker (1958) noted that the span of recognition does increase from first grade to fifth grade as subjects gain experience in reading. Rubino and Minden (1973) found that in eleven year olds, the span of recognition of poor readers is about half that of normal readers. These findings may indicate the importance of the use of structural and orthographic information in reading. This aspect of reading behavior is also important in determining the processes which are critical to the development of normal reading.

This section has been concerned with the problem of defining the unit of analysis in reading verbal stimuli. In the next section there will be a discussion of the experimental techniques used to analyze the encoding of verbal stimuli while reading.

Methods for Studying the Encoding of Verbal Stimuli

There are three techniques for investigating responses to physical features of visual stimuli. In the first of these, tachistoscopic recognition, a visual stimulus is presented for a brief period of time, and the subject tries to report the items present in the stimulus display. For example, one or more letters may be presented for $1/10$ to $1/2$ of a second, and the subjects report as many of the

letters as they can. The second technique is choice reaction time. Subjects are shown a visual stimulus and are required to react as quickly as possible to some feature of the stimulus. For example, the subject may be shown two letters, and then be required to indicate whether the letters are the same or different. The third technique is visual search, which is a variation of the choice reaction time experiment. Subjects are shown a visual display in which a target is embedded. The subject's task is to search the display for the target and respond as quickly as possible when the target is found. These three techniques all require the subject to respond discriminatively to some feature of a visual stimulus. The subject's response can be manipulated by requiring him to attend to a particular feature of the stimulus.

Tachistoscopic Recognition and Iconic Storage

Several variables are important in tachistoscopic recognition experiments. First of all, accuracy of report is affected by the duration of the stimulus. The longer the stimulus is present the more accurate is the subject's report. Accuracy is also affected by whether the stimulus is followed by a mask. The masking stimulus may be a flash of light or a random series of lines and dots. When the stimulus is not followed by a mask it seems to persist in

the visual field for up to 250 milliseconds after stimulus offset. Evidence for this phenomenon comes from an experiment by Sperling (1960). He presented 3 x 3 matrices of letters to subjects for very brief periods (50 milliseconds) and had subjects report as many of the letters as they could. He found that subjects could only report 3 to 4 letters correctly. Then he modified the procedure such that the subject would only be asked to report one row of letters, but the subject would not know which row until after stimulus offset. This was done by sounding a tone which cued the subject as to which row he was to report. He found that accuracy was high as long as the tone followed the visual stimuli by less than 250 milliseconds. Since the subject did not know which row was to be reported until the display had ended, he must have been able to store almost all the information from the display until the tone was sounded. A similar delayed report procedure was used by Averback and Coriell (1962). They presented subjects with a visual stimulus which consisted of a row of ten letters. The stimulus was presented for 100 msec., and was followed by a marker over the point where one of the letters had been. If the delay between the stimulus and the marker was less than 250 msec., accuracy of report was high. Again this suggests that the subject stores a copy of the stimulus after it is no longer present.

The concept of iconic memory or brief visual storage has emerged as a result of these studies of responding to briefly presented visual displays. This concept is used to describe the first internal representation of a visual stimulus. The characteristics of the store are such that the stimulus is represented as a literal copy of the display. The duration of the stimulus trace is very brief and rapidly deteriorates with time.

Because the representation of material in iconic memory is thought to be a literal copy of the visual input, it is relatively unaffected by familiarity, meaningfulness and experience. A critical factor then is the rate at which information is extracted from the icon. Rate of information extraction is studied with a backward masking procedure. In this procedure the target stimulus is followed by a visual noise stimulus after some brief interval. Visual noise consists of a random collection of lines and dots which form a meaningless pattern on a white background. Sperling (1963, 1967) investigated the relationship of stimulus duration to accuracy of report for random letter sequences in tachistoscopic recognition. The longer the delay of the mask the more accurate was the subject's report. The absolute duration of the stimulus was less important than the length of the interval between the onset of the target stimulus and the onset of the mask. Thus the

presentation of the mask seems to interrupt the extraction of information from iconic storage. Sperling found that subjects were able to report about one letter for every ten to fifteen milliseconds of time the icon was available.

Choice Reaction Time

The second technique for investigating responses to physical feature information is choice reaction time. One example is the character classification task of Posner (Posner and Mitchell, 1967; Posner and Keele, 1967; Posner, Boies, Eichelman, and Taylor, 1967). In this task a subject is required to indicate whether a pair of letters is the same or different by pressing one of two response keys. Response latencies are compared for stimulus pairs where subjects are instructed to match the letters on the basis of physical characteristics (do the letters look the same) or on the basis of letter names (Bb), or on the basis of a higher order rule (are the two letters both vowels). The different comparisons are assumed to reflect different processing requirements. For example, physical matches are made much faster than letter name or rule matches. When a delay is imposed between presentation of the two members of the pair (e.g. B followed by b after a delay), the difference in reaction time between physical and letter name or rule matches is reduced. This may indicate that name and

rule matches require subjects to react on the basis of labels which are available in memory and thus require extra time to retrieve that information from memory. It has also been found that physical matches are slower for visually similar letters, (e.g., O and Q), while visual similarity has no effect on name matches. On the other hand, name matches are slower if the stimuli have similar sounding names (Posner and Taylor, 1969). These differences again indicate differences in processing requirements.

Visual Search

The third technique which is used for assessing responses to physical feature stimuli is visual search. This requires the subject to locate a target item that is embedded in a visual display. In early studies by Neisser (Neisser, 1963; Neisser and Beller, 1965; Neisser and Stoper, 1965) subjects scanned 50-line lists with each line consisting of random letter strings. Subjects were instructed to press a button as quickly as possible when they located a target letter. The time to scan a row was computed by dividing search time into the number of rows prior to the target item. Neisser assumed that the time taken per row would reflect the complexity of the response required in the search task. He found, for example, that looking for the absence of a letter on line took more time

than looking for the presence of a letter on a line (Neisser, 1963). Thus looking for the absence of a letter is a more complex response. He also found that it was easier to find a Q against a background of angular letters than against a background of rounded letters. Conversely it was easier to find a Z against a background of rounded letters. Thus, search is faster if features which differentiate targets from nontargets are easy to discriminate. This seems to show that subjects can search for targets on the basis of critical features without fully identifying each letter in the display. In fact, Neisser reported that subjects were unable to identify nontarget items on a recognition task following the search task. Neisser also showed that subjects can learn to search for multiple targets without increasing search times (Neisser and Lazar, 1964; Neisser, Novich, and Lazar, 1963). Thus subjects can attend to several features which distinguish targets from their backgrounds

Subjects are also able to use redundancy to increase search speeds. Kreuger et al. (Kreuger, 1970; Kreuger, Keen, and Rublevitch, 1974) have shown that subjects of various ages can find a target letter in a list of words or letter strings which resemble words faster than in lists consisting of random sequences of letters. Kreuger (1970) also found that subjects search faster for target words in

coherent sentences than in a sentence in which the word order has been scrambled.

Visual, Acoustic, and Semantic Encoding of Verbal Stimuli

In this section there will be a discussion of the results from studies using these techniques to compare visual, acoustic and semantic feature analysis. There will also be a discussion of the hypotheses that have been put forth to account for the differences noted among visual, acoustic and semantic analysis. Then the five experiments which were conducted to test these hypotheses will be presented.

Initial work on the different characteristics of visual (physical feature), acoustic, and semantic encoding was carried out by Cohen (1968, 1970). In her first experiment, Cohen (1968) used a task in which subjects were required to decide whether one syllable words were identical visually, acoustically, or semantically. For visual decisions, subjects were to respond "yes" if the two words were printed exactly alike. For acoustic decisions subjects were to respond "yes" if the two contained an identical sound (e.g., rhyme). For semantic decisions subjects were to respond "yes" if the two words were synonyms (e.g., cap - hat). Visual decisions were fastest and semantic decisions

were slowest. She concluded that the visual aspect of a word is accessed first and the semantic aspect last. In a second experiment (Cohen, 1970), subjects searched for a specified target in a paragraph while reading the passage for meaning. The targets were defined visually (a specific letter), acoustically (a specific sound), or semantically (an instance of a category). In contrast to the previous findings, semantic targets were detected faster than visual and acoustic targets. Embedding the target in context produced an order of access which differed from that found in the absence of context. Cohen felt that of the three tasks, search for a member of a category was the most compatible with reading a passage for meaning since the subject could make use of contextual clues from the text.

Ball, Wood, and Smith (1975) looked at the effects of context by embedding the target in either a normal sentence or in a sentence in which the order of the words had been scrambled. Thus if context could be disrupted then the superiority of semantically defined targets should be diminished. They found that semantic targets were found faster in both cases, and concluded that context effects were negligible. They suggested instead that semantically defined targets are found faster because "semantic units of processing" are available to short-term memory processing before acoustic or visual units. This would seem to imply

that subjects can react to a visual stimulus faster when it is defined semantically than when it is defined visually or acoustically. Cohen's (1968) finding that subjects were able to respond to physical matches faster than acoustic or semantic matches seems to be in conflict with this idea. In addition, Craik and Tulving (1975) found that subjects respond faster when they are asked to state whether a given stimulus is printed in capital letters than when they are asked to state whether it rhymes with a given word, or when they are asked whether it is a member of a given category. These results seem to indicate that subjects can respond fastest to the visual characteristics of a word and slowest to the semantic characteristics of a word.

However, there are some procedural differences between these experiments and the visual search task. For example, the tasks used by Craik and Tulving (1975) and Cohen (1968) require subjects to choose between alternative responses (either "yes-no" or "same-different"). In the search task the subject simply responds when he detects the target. In addition, the definition of targets varies from one study to another. For example, Craik and Tulving and Cohen (1968) defined acoustic decisions in terms of rhymes, while Bail et al. and Cohen (1971) defined acoustic targets in terms of phonemes. Craik and Tulving defined structural (visual) stimuli in terms of upper or lower case letters,

while Cohen and Ball et al. defined structural stimuli in terms of the presence of a specific letter, i.e. the target word contained one or more specified letters.

A third explanation of faster search times for semantic targets has to do with the number of words subjects can respond to simultaneously. When words are presented one at a time, subjects can respond only to that one word. In a paragraph, subjects can view and possibly react to several words at a time. The ability to react to more than one word at a time would be facilitated by the effects of context. That is, the sequential redundancy in English allows subjects to take in large units or chunks of verbal material at a time when it is presented in normal form. However, it is also possible that subjects are able to react to several words simultaneously without the facilitative effects of context. In either case, if semantic processing allows a subject to handle more words simultaneously than acoustic or visual processing, then the superiority of semantic search would not be surprising.

These three explanations of faster semantic search times assume that decision time is the only critical factor in determining search speed. It may be, however, that there are differences in the amount of physical or visual feature information necessary to make visual, acoustic, and semantic

decisions. That is, a subject may have to attend to more of the letters present in the stimulus if he is given a rhyme or acoustic clue to the word, than if he is given a category or semantic clue. Thus faster semantic search might occur because the subject does not have to attend as closely to each word when he is given a category clue.

In summary then, four hypotheses can be delineated to explain the superiority of semantic targets in visual search. First, Ball et al. suggest that units of processing are available to short-term processing before visual or acoustic units. A second hypothesis is that search for semantic targets through prose passages is facilitated by the presence of a meaningful context. The third hypothesis is that when subjects are looking for a semantically defined target, they may be able to simultaneously react to more words than when they are looking for an acoustically or visually defined target. The fourth hypothesis is that semantic targets are found faster in search tasks because less physical feature information is necessary to make a semantic decision about a word than is necessary to make an acoustic or visual decision. Five experiments were conducted in the present research to evaluate the merits of these hypotheses. These experiments are outlined below.

First, Ball et al. suggest that semantic units become available to short-term processing before visual or acoustic units. This hypothesis is contraindicated by the results of Craik and Tulving (1975) and Cohen (1968). However, in these experiments, subjects were required to react to visual stimuli in a way which is different from what is required in a search task. Specifically, these tasks required a choice between two responses, while in the search task, the subject simply indicates when a target is detected. Thus, subjects might react faster to semantic aspects of a stimulus word when he is required to make a simple recognition response. Experiment 1 tested the hypothesis of Ball et al. that semantic units become available before visual or acoustic units. In this experiment subjects were required to respond to targets defined either visually, acoustically, or semantically. The task differed from that used by Craik and Tulving (1975) and Cohen (1968) in that the subject was not required to choose between alternative responses. It is possible that the results obtained by these researchers reflect in part, time to make a decision between two responses, which is not required in the search task. That is, the subject was required to respond as quickly as possible when he or she recognized the target item. Items were presented one at a time, however, so that the reaction time differences reflected the speed with which different units are available

for processing.

The second hypothesis accounting for the superiority of semantic targets in visual search regards the effects of context. The presence of a meaningful context may facilitate search for a semantically defined target while not facilitating search for targets defined visually or acoustically. If this is so, then the superiority of semantic targets in visual search should be less when context is disrupted. Experiment 2 was used to evaluate the effects of context on different types of processing. Subjects searched through paragraphs for target words defined visually, acoustically, and semantically. In one condition, the order of the words in the paragraphs was scrambled so that they no longer were meaningful. Thus context was manipulated by disrupting word order. If context is important to the semantic superiority effect, then the disruption of context should decrease the superiority of semantic targets.

A third experiment was conducted to show the magnitude of the semantic superiority effect when context effects are eliminated. If subjects can handle no words simultaneously while looking for a semantic target, then semantic search should be superior when context effects are eliminated. Context effects were eliminated by having

subjects search displays consisting of words drawn at random for targets defined visually, acoustically, or semantically.

The third hypothesis is that when subjects are looking for a semantically defined target, they will react simultaneously to more words than when they are looking for an acoustically or visually defined target. That is, while letter and rhyme search tend to be word by word processes, subjects tend to respond to more than one word at a time when searching for semantically defined targets. This hypothesis can be tested by manipulating serial position of the target in a choice reaction time task. If letter and rhyme search are word by word processes, reaction time should increase in a linear fashion with serial position of the target. In semantic search, if response units are larger than a single word then the relationship between reaction time and serial position should not be strictly linear. Instead, reaction time for words within a single response unit should be identical. Therefore, there should be points at which speed of reaction to words in adjacent serial positions should not differ. In Experiment 4 the hypothesis that response units in letter and rhyme search are smaller than those in category search was tested. Subjects were presented five words on each trial and they decided whether any of them fit in a given letter, rhyme, or category clue. It was hypothesized that while reaction time

for letter and rhyme clues would increase in a linear fashion with serial position of the target, reaction time for category targets would be characterized by a pattern which reflects larger response units. That is, speed of reaction should not differ between words at every serial position.

The fourth hypothesis is that semantic targets are found faster in search tasks because less physical feature information is necessary to make a semantic decision about a word than is necessary to make an acoustic or visual decision. This hypothesis would imply that subjects should be able to monitor more words for meaning than for sound when the words are presented for a given period of time. This notion was tested in Experiment 5. Subjects were to try to detect a target word defined visually, acoustically, or semantically in a briefly presented visual display. It was expected that semantic targets would be detected more accurately than acoustic targets in this experiment.

Research Hypotheses

In summary, the research hypotheses investigated in this series of experiments were as follows:

1) Visual and acoustic units are available for processing more rapidly than semantic units; thus it was expected that speed of reaction to semantic targets would be greater than reaction time to acoustic and visual targets in Experiment 1.

2) Context aids semantic search but inhibits search for acoustic and visual targets. It was expected that in Experiment 2 search for semantic targets would be faster than search for acoustic and visual targets in normal paragraphs. This would be in line with Cohen's (1970) results. It was further expected that search times for semantic targets would be longer when the words in the paragraphs are scrambled than when the word order is normal. At the same time, the disruption of context in the form of scrambled word order should cause acoustic and visual targets to be detected faster than they are in normal paragraphs. Specifically, semantic search should be faster in both normal and scrambled paragraphs

but that the differences between search for the three types of targets will be much smaller with scrambled paragraphs. Thus there should be a significant interaction between target type and context. Experiment 3 was conducted to find out how important context was in semantic search by eliminating semantic redundancy in paragraph search.

3) When subjects are required to react to words semantically they should be able to handle more words simultaneously than when they are required to react to them acoustically or visually. Thus in Experiment 4 it was expected that reaction time to targets defined visually or acoustically would increase in a linear fashion with serial position of the target. It was expected that reaction time for semantic targets would not differ at every serial position.

4) Subjects require less physical feature information in order to make semantic decisions than to make acoustic decisions. Thus it was expected that subjects would be more accurate in detecting semantic targets than acoustic targets in Experiment 5.

Five experiments were conducted to evaluate these hypotheses. Target definition was held constant across experiments. Visually defined targets were defined in terms of their initial letters. Acoustic targets were defined in terms of rhymes, and semantic targets were defined in terms of category membership. In these experiments several factors were investigated including the role of response type (two separate responses vs. response - no response choice), the role of context, whether search could be viewed as a word by word process, and the amount of information necessary to make visual, acoustic and semantic decisions. In these experiments three types of tasks were used; choice reaction time, search, and tachistoscopic recognition.

In Experiment 1, the role of response requirements was investigated. The notion that Cohen (1968) and Craik and Tulving (1975) found slower semantic decision time because they required subjects to choose between alternative responses was put to test. In Experiments 2 and 3, the effects of disrupting word order and word frequency in search for visual, acoustic and semantic targets were investigated. The degree to which search for visual, acoustic, and semantic targets is a word by word process was investigated in Experiment 4. In Experiment 5 the relative amount of information needed to make visual, acoustic and semantic decisions was investigated.

CHAPTER 2

EXPERIMENT 1

The tasks employed by Cohen (1968) and Craik and Tulving (1975) required a choice between two overt responses (either same-different or yes-no) while in the search task, the subject simply responds as quickly as he can when he detects the target. Subjects might be able to respond faster to semantically defined targets when a choice between two overt responses is not required. In Experiment 1 this notion was put to test. In this experiment subjects were required to respond to targets defined either visually, acoustically, or semantically. The task differed from that used by Craik and Tulving (1975) and Cohen (1968) in that the subject was not required to choose between alternative responses. It is possible that the results obtained by these researchers reflect in part, time to make a decision between two responses, which is not required in the search task. The identification task used in Experiment 1 was identical to that used in a search task. That is, the subject was required to respond as quickly as possible when he or she recognized the target item. Items were presented one at a time, however, so that the reaction time differences would reflect the speed with which different units are available for processing.

Method

Subjects

Subjects were 30 undergraduate students recruited from introductory psychology courses at Georgia Tech. They received class credit for participating in the experiment.

Materials and Apparatus

The stimuli were 180 common (AA Thorndike & Lorge, 1944 general count) English nouns, adjectives, and verbs. Slides were prepared with one word in "pica" typeface on each slide. A Kodak carousel slide projector was used to present the stimuli. The distance from the projector to the screen on which the slides were presented was six feet. The subject sat four feet from the screen. The presentation rate of the slides was controlled by a Lafayette interval timer. Reaction time was measured by a Hunter Klockounter (model 120A), to the nearest millisecond. The clock was operated by a microswitch which the subject held in his preferred hand.

Thirty of the 180 words were selected as target words to which the subject was to respond. A set of slides was prepared which contained the clues to the thirty target

words. For each target word there was a visual feature clue (the first letter of the word) an acoustic feature clue (another word which rhymed with the target word, e.g. "rhyme-fair" would be the clue for the target word "bear"), and a semantic feature clue (a category to which the target word belonged). The rhyme words were chosen so that the rhyme sound did not always contain the same letters (e.g. boot-suit, as opposed to boot-root). The clue word always had the same number of syllables as the target word, and all syllables of both the words rhymed. The rhymes were checked in the Capricorn Rhyming Dictionary (Redfield, 1964). The category clues were obtained from general sources, including category norm tables (Battig & Montague, 1969; Hunt & Hodge, 1971) as well as the table of categories used by Craik and Tulving (1975).

A list of the target words and their corresponding rhyme and category clues is given in Table 1.

Procedure

The subject sat before a screen on which the stimuli were presented. There were 30 trials per subject. For each trial there was a particular target word. The subject was presented a clue to the target word on the screen, while the experimenter read it aloud. The subject then monitored a

Table 1. Target Words, Rhyme, and Category Clues
for Experiments 1 and 3

<u>TARGET</u>	<u>RHYME</u>	<u>CATEGORY</u>
1. Brown	crown	Color
2. Queen	scene	Member of royalty
3. Inch	pinch	Measure of distance
4. Door	more	Part of a room
5. Milk	silk	Something you drink
6. Shoe	true	Kind of footgear
7. Coal	goal	Kind of fuel
8. Story	glory	Something you read
9. Head	said	Part of the body
10. Food	mood	Something you eat
11. Square	pair	Geometrical shape
12. Flower	tower	A plant
13. Wife	knife	Relative
14. Mouth	south	Part of a face
15. Morning	warning	Time of day
16. Ball	call	A toy
17. River	liver	Body of water
18. Dress	less	Article of clothing
19. Twenty	plenty	Number
20. Dollar	collar	Kind of money
21. Rose	nose	Flower
22. Bird	third	Animal
23. Winter	printer	Season of the year
24. Train	grain	Vehicle
25. Table	cable	Article of furniture
26. East	least	Point on a compass
27. Week	seek	Measure of time
28. Church	birch	Building
29. Judge	grudge	Profession
30. Pound	round	Measure of weight

series of words presented one at a time on the screen for a word which fit the clue and responded as soon as he recognized it.

For one-third of the trials the clue was the first letter of the target word; for one-third it was a rhyming word; and for one-third it was a category to which the word belonged. The words were presented at a rate of one word every 1.5 seconds. The target word could appear at any point in the series from the second to the eleventh word. As soon as the target word was presented a Hunter Klockounter was activated. When the subject recognized the target word, he pressed the microswitch which in turn stopped the clock. The time, in msec., was then recorded for that trial. No distinct auditory signal from the equipment occurred to cue the subject when the Klockounter was activated.

None of the words that preceded the target word in a given series fit the clues to that target word. The subject was told that the rhymes were based only on the sound of the word and that any one target word may or may not have the same letters as its clue word. They were also told that the targets would have the same number of syllables as the rhyming clue word. If a subject accidentally pressed the microswitch before the target was presented, this was

considered an error and the trial was repeated only once.

There were three practice trials, one for each type of clue before the thirty recorded trials began. The clue types for each target word were counterbalanced across subjects. The order of types of clues was irregular across the thirty trials. All three clues were used for all target words an equal number of times in the experiment.

Results

Median latency scores of correct responses for each type of clue were computed for each subject. These scores were analyzed in a one-way analysis of variance with clue type as a within subject factor. Means of these scores are presented in Figure 1. Mean reaction time for the first letter clue was fastest while mean reaction time for category clue was the slowest. The main effect of clue type was significant, $F(2,58) = 78.78$, $p < .01$. Dunn's multiple comparisons procedure (Kirk, 1968) revealed that the letter clue led to significantly faster reaction times than either the rhyme ($p < .01$) or the category clue ($p < .01$), and that the rhyme clues led to faster responses than the category clues ($p < .01$). The number of errors was not a critical factor in this experiment. They occurred on less than 2% of the trials.

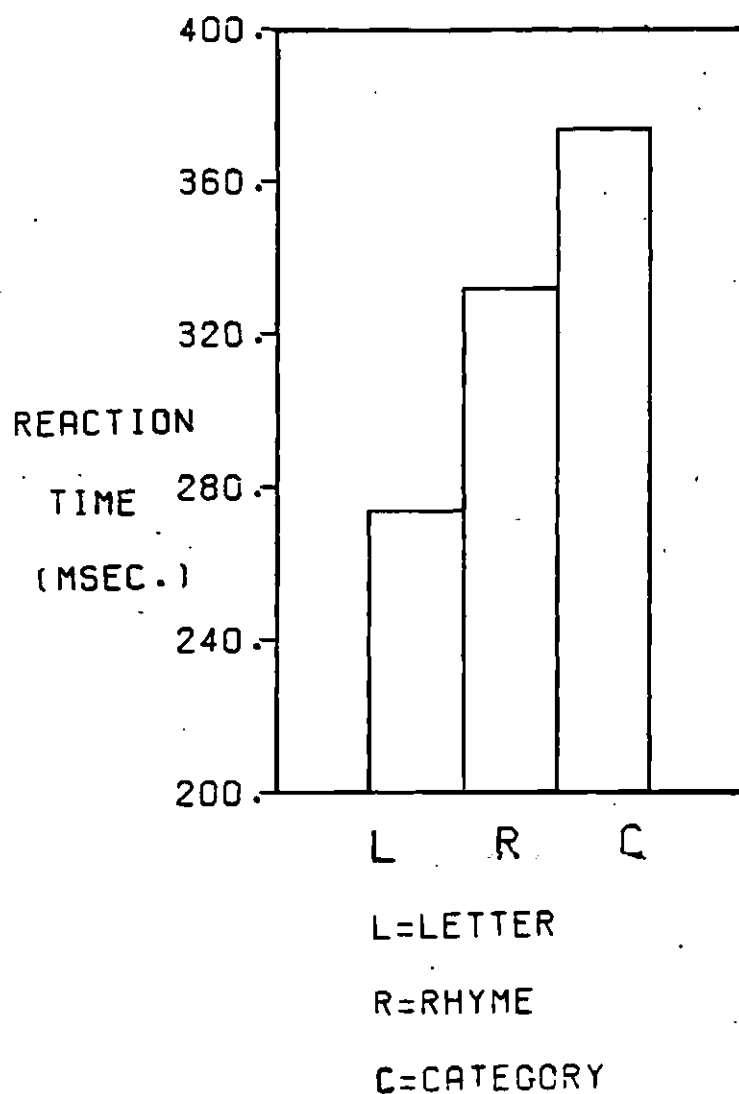


FIGURE 1

SIMPLE REACTION TIME
AS A FUNCTION OF TARGET TYPE
(EXPERIMENT 1)

The results of Experiment 1 give further support to the findings of Craik and Tulving (1975) and Cohen (1968) that semantic decisions take longer than acoustic or structural decisions. Experiment 1 shows that semantic decisions are slower when the subject does not have to choose between two overt responses.

CHAPTER 3

EXPERIMENT 2

Experiment 2 was aimed at clarifying the role of context in Cohen's search task. In the study by Ball et al. (1975), subjects searched through sentences for targets defined visually, acoustically, or semantically. It was found that semantic targets were found faster than acoustic or visually defined targets and that the superiority of semantic targets was not affected by scrambling the word order of the sentences. They concluded from their results that context did not account appreciably for faster semantic search.

It may be argued that the context effects that Cohen (1971) suggests are responsible for faster semantic search are not given sufficient chance to operate when subjects search through a single sentence at a time. Perhaps semantic redundancy, that is, the interrelation of the meaning of words in a passage, acts to facilitate semantic search, but that this cannot occur until the subject has searched a considerable part of the passage. For example, in the Ball et al. study semantic search may have been facilitated in normal sentences only when the target

occurred at the end of the sentence. Unfortunately, these researchers did not report the effects of serial position of targets. If semantic redundancy facilitates search for semantic targets when scrambling word order may differentially affect semantic search when the target is embedded in a longer prose passage.

Experiment 2 was conducted to determine if semantic search is affected by scrambled word order when the target word is embedded in a paragraph. Target definitions for acoustic and semantic targets were identical to those used in Experiment 1 in order to allow for direct comparison across experiments. It was necessary to modify the target definitions for structural targets such that the clue became the first two letters of the word. This was done because it was impossible in many cases to uniquely specify the target word in the paragraph with only the first letter of the word. In addition, serial position of targets was varied and its effects in this experiment were analyzed.

Method

Subjects

Subjects were 48 undergraduate students recruited from introductory psychology courses at Georgia Tech. They received class credit for participating in the experiment.

Subjects were randomly assigned to experimental conditions.

Materials and Apparatus

Stimuli were 27 paragraphs taken from college level reading materials, including textbooks and magazines. Paragraphs covered a range of topics including history, economics, exploration, science, and current events. For each paragraph there was one target word. Target words were chosen so that they could be uniquely specified in the paragraph with the types of clues used (first two letters, rhyme word, category) in this experiment, and so that a broad range of each type of clue could be obtained. For each target word there was a visual feature clue (first two letters of the word), an acoustic feature clue (another word which rhymed with the target word), and a semantic feature clue (a category to which the target word belonged). The rhymes and category clues were chosen in the same manner as those in Experiment 1. A list of the target words and their corresponding rhyme and category clues is given in Table 2.

Paragraphs were photographed and slides prepared with one paragraph on each. Paragraphs were typed on an IBM selectric typewriter using "pica" type face. Slides were also prepared with the clues to the 27 target words on them. A carousel slide projector was used to present the stimuli.

Table 2. Target Words, Rhyme, and Category Clues for Experiment 2

<u>TARGET</u>	<u>RHYME</u>	<u>CATEGORY</u>
1. Coal	goal	Kind of fuel
2. Dime	chime	Coin
3. Lakes	cakes	Body of water
4. Boat	note	Vehicle
5. Shark	mark	Fish
6. Pear	fair	Fruit
7. Silks	milks	Kind of cloth
8. Church	birch	Building
9. Winter	printer	Season of the year
10. Story	glory	Something you read
11. Judge	grudge	Profession
12. Geese	cease	Bird
13. Miles	files	Measure of distance
14. Five	dive	Number
15. White	tight	Color
16. West	best	Point on the compass
17. Hour	sour	Measure of time
18. Eyes	pies	Part of a face
19. Steel	heel	Metal
20. Bees	fees	Insect
21. Deer	hear	Mammal
22. Floor	more	Part of a room
23. Boots	roots	Kind of footgear
24. Priests	feasts	Member of the clergy

Search time was recorded by a Hunter Klockounter, and was operated by a microswitch which the subject held in his preferred hand. The Klockounter was activated as soon as the stimulus was presented.

Procedure

All subjects searched through 24 paragraphs for targets defined visually, acoustically or semantically. On each trial the subject was given a clue to the target word. Then the paragraph was presented and the subject searched through the paragraph left to right, line by line, for a word which fit the clue. As soon as he found the target word the subject pressed a microswitch which he held in his hand and then reported the target word. Then the search time was recorded.

For half the subjects the paragraphs were unaltered. For the other half the order of the words were scrambled in a random fashion with the restriction that all words remained on the same line as in the original version, and also that the target word remained in the same position on the page such that the very same words preceded the target in both versions.

For one-third of the trials the clue was the first two letters of the target words; for one-third it was a rhyming word; and for one-third it was a category to which the target belonged. There were three practice trials, one for each type of clue before the 24 recorded trials began.

If a subject failed to find the target on the first pass through the paragraph he was instructed not to start over. Instead the clock was reset and the subject was given a second pass through the paragraph. Subjects were not allowed a third pass through if they missed twice. Each failure to find the target was considered a error.

Target position was also manipulated in this experiment. Paragraphs were divided into eight groups of three each according to the position of the targets in each. The average position (number of words preceding) the targets in each group ranged from 15 to 96. The eight paragraphs for each clue type (letter, rhyme, or category) were chosen so that all eight average target positions were represented for each.

None of the words that preceded or followed the target word fit the clues to that target word. The subject was told that the rhymes were based only on the sound of the word, and that any one target word might or might not have

the same letters as its clue word. They were also told that the targets would have the same number of syllables as the rhyming clue word.

The clue types for each target word were counterbalanced across subjects as in Experiment 1. The order of types of clues was irregular across the 30 trials. All three clues were used for all target words an equal number of times in the experiment.

Results

The data from Experiment 2 were analyzed in two separate ways. The first analysis, based on mean scores, was performed in order to analyze the effects of serial position of the target item. Search times were converted into word per minute scores. These scores were analyzed using an analysis of variance with context as a between subject factor, and target type and target position as within subject variables. The main effect of context (normal vs. scrambled paragraph) was not significant ($F < 1$). There was a significant effect of target type, $F(2,1058) = 20.113$, ($p < .01$). The mean scores as a function of target type and context are given in Figure 2. It can be seen that search times were fastest for semantically defined targets and slowest for acoustically

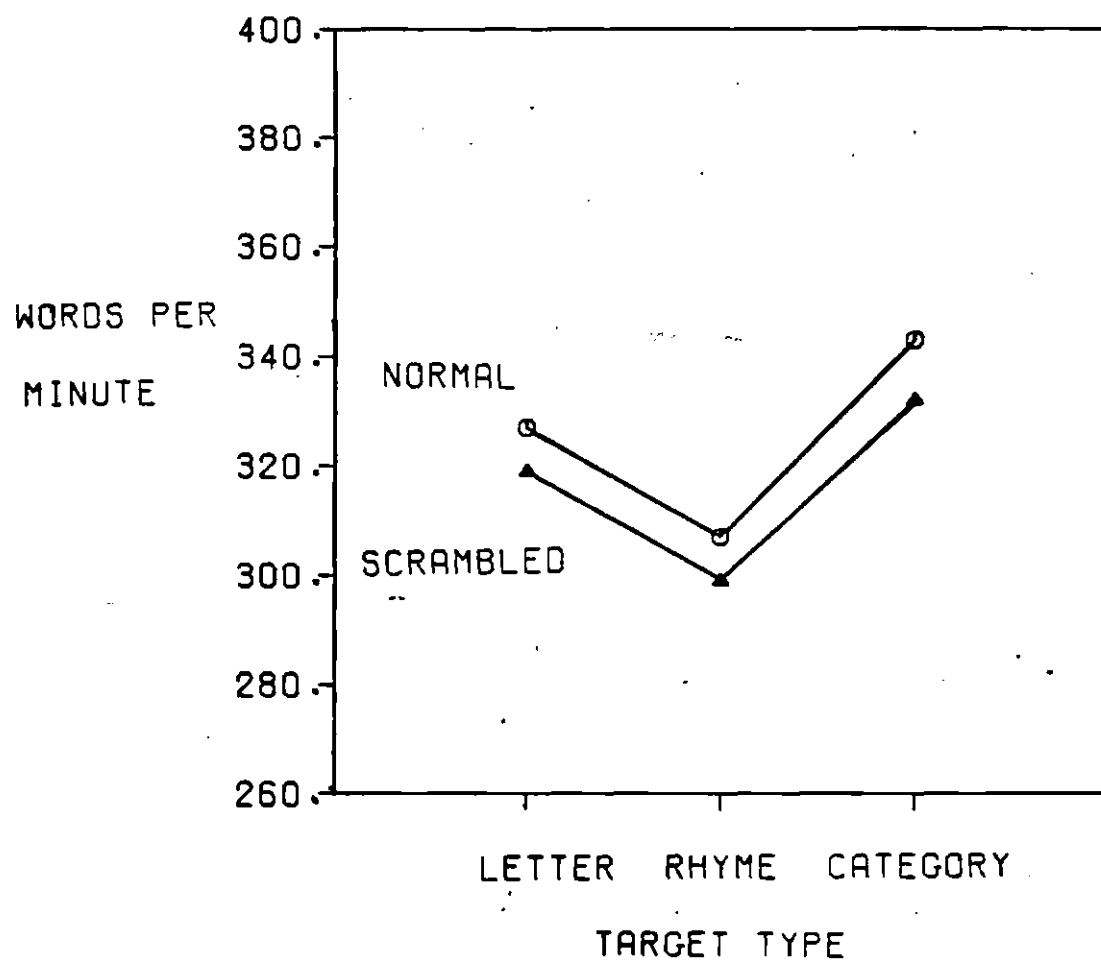


FIGURE 2
SEARCH SPEED AS A FUNCTION
OF TARGET TYPE AND CONTEXT
(EXPERIMENT 2)

defined targets. Multiple comparisons using Dunn's procedure revealed that all pairwise comparisons between the three target types were significant ($p < .01$). There was also a significant effect of target position ($F(7,1058) = 18.457, p < .01$). In general speed increased when the targets occurred later in the paragraph. This may reflect a general tendency to use context to facilitate search. This is discussed in more detail below.

The only significant interaction was that between target type and serial position $F(14,1058) = 4.067, p < .05$. Speed of response as a function of target type and serial position of target is illustrated in Figure 3. It can be seen that, in general, speed of response increased as a function of position in the paragraph for the rhyme and category targets, but changed very little as a function of target position for the letter targets. This result suggests that there is some effect of context, but that it facilitates acoustic search as well as semantic search. In addition, the results indicate that semantic search was fastest both in normal and in scrambled paragraphs. These results replicate the findings of Cohen (1971) and Ball et al. (1975) and indicate that disrupted context, in the form of altered word order, does not affect the finding of faster semantic search in paragraphs.

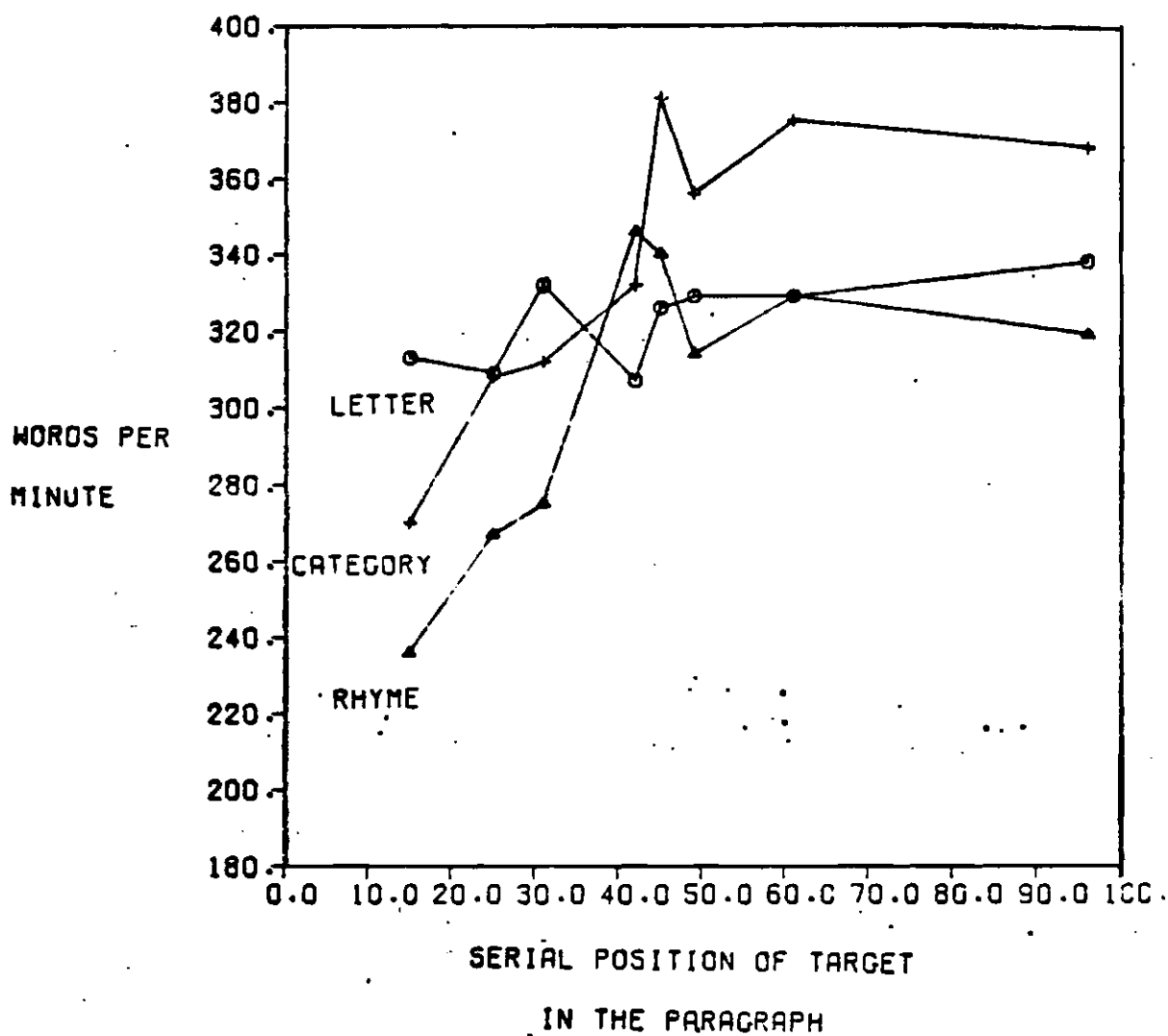


FIGURE 3

SEARCH SPEED AS A FUNCTION
OF TARGET TYPE AND POSITION
(EXPERIMENT 2)

It can be argued that with search and reaction time measures, the median is a more sensitive measure of central tendency for a given subject than the mean, because the median is less affected by extreme values (Spence, Cotton, Underwood, & Duncan, 1976). For this reason, a second analysis of the data from Experiment 2 was performed in which serial position of the target was ignored and each subject's median word per minute score for each target type was used. Again an analysis of variance was computed on these scores with context as a between subject variable and target type as a within subject variable. Search speed as a function of target type and context using this analysis is shown in Figure 4. The main effect of context was not significant ($F < 1$). The main effect of target type was significant ($F(2,84) = 15.915, p < .01$), while the interaction between context and target type was not significant ($F(2,84) = 1.826$).

Dunn's multiple comparison procedure revealed that category targets were found significantly faster than either rhyme or letter targets ($p < .01$) but that there was no difference in search speed between letter and rhyme targets. It can be seen from Figure 4 that targets were found faster when the word order of the paragraphs was not scrambled, and that this held true for all target types, but the difference was greatest for the category targets. Multiple comparisons

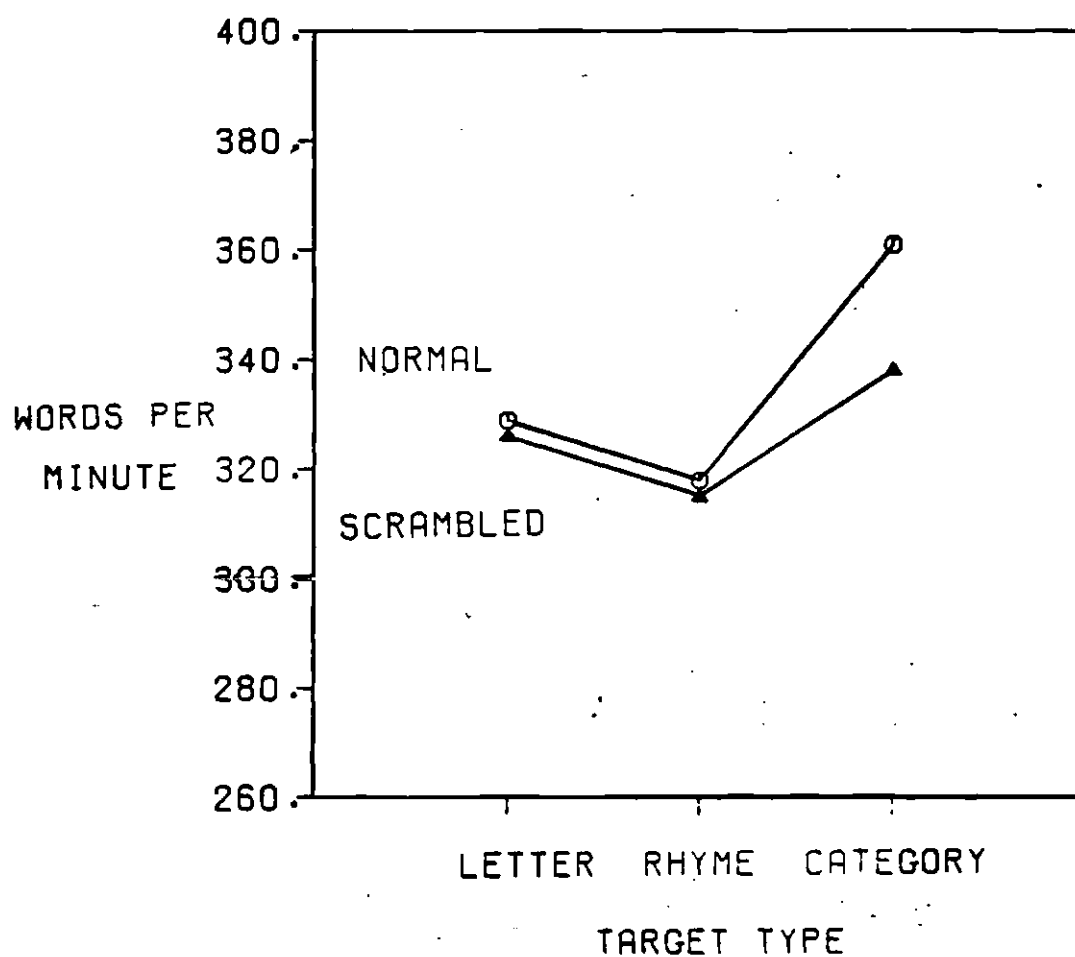


FIGURE 4
SEARCH SPEED AS A FUNCTION
OF TARGET TYPE AND CONTEXT
(EXPERIMENT 2)

showed that search time for category targets was significantly faster ($p < .01$) when the context of the paragraph was not altered, while the differences for rhyme and letter targets were not significant. These results suggest that context in the form of altered word order does affect search for semantically defined targets and that this was not found previously because the analyses were based on mean search speeds instead of median scores. In any case the magnitude of the differences found were small, and it cannot be concluded that context effects account entirely for faster semantic search speeds.

The faster search time for category targets was not due to a decrease in accuracy of performance. The overall error rate in Experiment 2 was 11%. The rate of error was the same in both normal and scrambled paragraphs. The error rate for rhyme targets was higher (17%) than that for either letter (8%) or category targets (9%). Thus the faster search time for category targets was not associated with an increase in errors.

CHAPTER 4

EXPERIMENT 3

The results of Experiment 2 are somewhat puzzling. It can be argued that subjects are able to make use of contextual information from the redundancy available in paragraphs to increase search speed for semantic and acoustic targets because, in the analysis of mean scores, search speeds increased for semantic and acoustic targets as targets were placed further along in the paragraph. Disrupting word order had only a small effect on search times for semantic targets. Perhaps some other form of redundancy available in paragraphs is responsible for faster semantic search, and this redundancy is not affected by disrupting word order. For example, semantic redundancy available from key words may lead to faster search times for semantic targets.

Experiment 3 was conducted to determine if faster semantic search could be eliminated by eliminating virtually all possible sources of redundancy in a paragraph. Subjects searched through lists of randomly selected words arranged in paragraph form for targets defined visually, acoustically, and semantically as in Experiment 2.

Method

Subjects

Subjects were 18 undergraduate students recruited from introductory psychology courses at Georgia Tech. They received class credit for participating in the experiment.

Materials and Apparatus

The stimuli were 33 random lists of words, typed in paragraph form. Each list was 90 words long, and all the words were chosen from a pool of 500 common English nouns, adjectives, and verbs (AA Thorndike & Lorge, 1944 words). The paragraphs were typed on an IBM selectric typewriter using "pica" type face. The paragraphs were photographed and slides were prepared with one paragraph on each. The paragraphs were presented using a Kodak Carousel slide projector as in Experiment 2.

The target words in the paragraphs were the same as those in Experiment 1. The target words along with their corresponding rhyme and category clues are presented in Table 1. The visual clues in this experiment were the first two letters of the target words. None of the words preceding the target words in a particular paragraph either

rhymed with the target word, had the same first two letters, or belonged to the category that was used as a clue to the target word. Reaction time was recorded in the same manner as in Experiment 2.

Procedure

The procedure was the same as that for Experiment 2, except that subjects searched through 30 random lists of words printed in paragraph form. The subject again pressed a microswitch and reported the word when he found it. Again there were three practice trials, one for each type of clue. Again, target position was manipulated in this experiment. Ten serial positions were used, ranging from 9 to 80. The ten paragraphs for each clue type were chosen so that all ten serial positions were presented for each. Instructions for this experiment were the same as for Experiment 2 except that subjects were told that they would be searching random lists of words arranged in paragraph order. The order types of clues was random across the thirty trials, and the clue types were counterbalanced across subjects.

Results

As in Experiment 2, two analyses were performed, one based on medians and one based on mean scores. The results

of the two analyses were the same and so only the analysis of the mean scores will be presented. Search times were converted into word-per-minute scores. These scores were analyzed using an analysis of variance with target type and target position as within subject variables. The main effect of target type was significant, $F(2,493) = 46.01$, $p < .01$. The mean scores per target type are given in Figure 5. It can be seen that search for visually defined targets was fastest. Post hoc comparisons showed that visual targets were detected faster than either rhyme or category targets ($p < .01$), but there was no difference in search times for rhyme or category targets. There was also a significant effect of target position, $F(9,493) = 6.15$, $p < .05$. In general, speed of search increased for targets located further on in the paragraph, but this increase levels off about halfway through the paragraph. The interaction between target type and serial position was not significant, $F(18,493) = 2.35$, suggesting that this increase was not different for different target types.

More errors were made in Experiment 3 than in Experiment 2. The overall error rate was 16%; the error rate for letter targets was 7%, for rhyme targets it was 21% and for category targets it was 19%. Thus the faster search speeds associated with letter search were not due to an increase in errors.

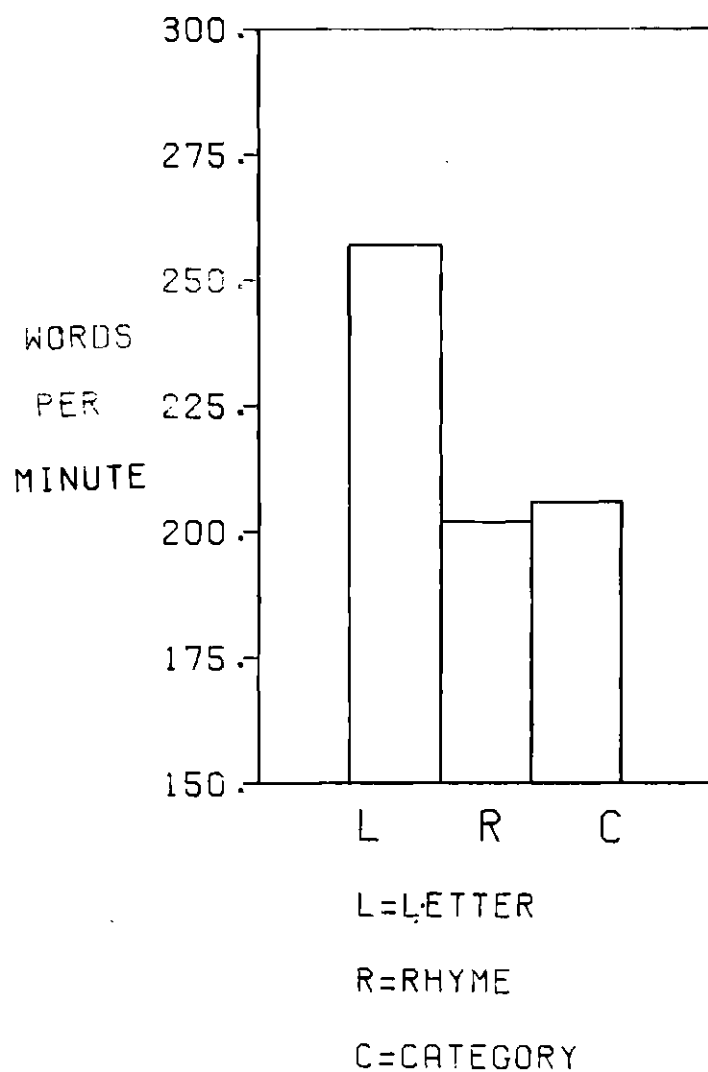


FIGURE 5

SEARCH SPEED THROUGH PARAGRAPHS
COMPOSED OF WORDS IN RANDOM ORDER
(EXPERIMENT 3)

The results of this experiment along with those of Experiment 2 suggests that context is important in demonstrating faster semantic search. When normal word frequency is preserved, subjects find semantic targets faster than visual targets even when word order is disrupted. When word frequency is disrupted as well, semantic targets are no longer found faster than visual or acoustic targets.

CHAPTER 5

EXPERIMENT 4

The lack of a difference between acoustic and semantic search time in Experiment 3 is interesting in light of the results of Experiment 1. If all redundancy were eliminated, then search for acoustic targets could be expected to be faster than search for semantic targets since semantic decisions are slower than acoustic decisions. This analysis, however, is based on two assumptions which have not been investigated. First it implies that search through the paragraphs used in Experiment 3 is basically a word by word process and that this is so for both rhyme and category targets. It is possible that when subjects search for a rhyme word they do so by examining each word one at a time, but that strategy in search for category words differs from this one word at a time process. It may be that somehow subjects can analyze more than one word at a time for category judgements. Thus, while category judgements would be slower if the subject responded to only one word, this difference would diminish if more than one word were present.

The second assumption is that decision time is the

main factor in determining speed of reaction in the search task. It is possible to analyze search as a two step process. In the first stage, the subject views the stimulus and decodes from it the information necessary to make the necessary decisions. In the second stage, the subject uses this information to decide if the target is present in this visual fixation. While the second stage may be longer for semantic targets, it might be that the first stage is longer for acoustic targets. That is the information necessary to make a semantic (category) decision can be decoded from the visual stimuli faster than the information necessary to make an acoustic (rhyme) decision. Thus subjects should be able to monitor more words for meaning than for sound in a given period of time.

These two notions were examined in Experiments 4 and 5. In Experiment 4 the hypothesis that rhyme search is a word by word process while category search is not was tested. In Experiment 5, the hypothesis that more information about the stimulus word is necessary for rhyme decisions was tested.

If reaction time reflects the number of units attended to, then differences in the size of the response units should be reflected by differences in the relationship between reaction time and target position. If search is a

word by word process then reaction time should increase in a linear fashion with serial position of the target. If, on the other hand, response units are larger than a single word then the relationship between reaction time and target position of the individual words should not be strictly linear. Instead, there should be no differences in reaction time for words within a single response unit. In Experiment 4 subjects were presented five words on each trial and they decided whether any of them fit a given letter, rhyme, or category clue. It was hypothesized that while reaction time for letter and rhyme clues would increase in a linear fashion with serial position of the target, reaction time for category targets would be characterized by a pattern which reflects larger response units. That is, discrete increases in reaction time should not occur for every successive serial position.

Method

Subjects

Subjects were 12 undergraduate students recruited from introductory psychology courses at Georgia Tech. They received class credit for participating in the experiment.

Materials and Apparatus

Stimuli were 240 sets of five different words each. The words were sampled from a pool of 600 common English nouns, adjectives, and verbs. Each word in the pool was used at least twice. The Thorndike & Lorge (1944) frequency varied from 1 per million to AA. Each set of words was typed on a white index card with an IBM selectric typewriter using oversized "pica" type face. One set of words was presented on each trial. For half of the trials one of the words was designated as the target word. For each target word there was a visual feature clue, an acoustic feature clue, and a semantic feature clue which were defined in the same manner as in Experiments 2 and 3. Subjects viewed the stimuli through a Gerbrands three field tachistoscope. In addition there were two microswitches in front of the subjects which served as response keys and which operated a Hunter millisecond clock. There was also a response button on the floor in front of the subject which was used to activate the tachistoscope and the Hunter clock at the beginning of each trial.

Procedure

On each trial the subject viewed five words simultaneously. His task was to determine if any of the

words fit a particular clue which he was given before the trial. A choice (yes/no) reaction time task was used to prevent the subject from responding before he actually recognized the target word. The subject was provided with a typed list of the clues. In addition the experimenter read the clue aloud before each trial.

Trials were run in 4 blocks of 65 each. The first five trials were not included in the analysis. There were two independent variables, clue type and serial position of target. For half of the remaining 60 trials, one of the five words did correspond to the clue while for the other half none of the words fit the clue for that trial. For one-third of these trials the clue was the first two letters of the target words; for one-third it was a rhyming word; and for one-third it was a category to which the target belonged. For each clue type the target occurred an equal number of times (twice) in each of the five serial positions in each block of trials. Thus across the four blocks of trials, there were eight trials for each combination of target type and serial position. The subject initiated stimulus presentation with a foot switch. When the subject pressed the switch a fixation stimulus was presented followed by the five stimulus words. The fixation stimulus was a gray square in the left visual field. It was presented for one second. Immediately following the

fixation stimulus the five stimulus words were presented for one second. The stimulus words were presented on a horizontal line two character spaces to the right of the fixation stimulus. The viewing distance was 28 inches, and the each character was $1/8$ inch in height. The visual angle subtended by each character was 16 minutes of arc.

When the subject initiated the stimulus presentation the millisecond clock was activated. The subject then pressed one of the two microswitches before him to indicate whether any of the words fit the clue. If he responded "yes" the experimenter asked the subject to identify the word. The speed of reaction was recorded for each trial.

There were eight practice trials before the recorded trials began. The order of clues was random across trials, and the clue types were counterbalanced across subjects.

Results

For each subject there were eight trials for each combination of target type and serial position. Median reaction times and number of errors per subject were calculated and analyzed in separate analyses of variance with clue type and target position as within subject variables. The error rate for targets defined visually

(first two letters) was 11%, for rhyme targets it was 15% and for semantic targets it was 12%. Neither of the main effects, target type or serial position, nor the interactions were significant for error scores.

Mean (of the subjects' median scores) reaction time as a function of target type and serial position are presented in Figure 6. The main effect of target type was significant ($F(2,154) = 14.671, p < .01$) as was that of serial position ($F(4,154) = 86.511, p < .01$). The interaction was not significant $F(8,154) = 1.191$. Mean reaction time for visually defined targets was 1.025 seconds; for rhyme targets mean reaction time was 1.124 seconds and for semantic targets it was 1.155 seconds. Dunn's multiple comparison procedure revealed that reaction time for visually defined targets was significantly faster ($p < .01$) than for either rhyme or semantic targets. There was no difference in reaction time between rhyme and semantic targets.

In addition there was a general tendency for reaction time to vary with serial position of targets. Targets in the fifth position had the slowest reaction times, while those in the first position had the fastest reaction times. Post hoc analysis (Tukey's HSD statistic, see Kirk, 1968) showed that there were significant differences between

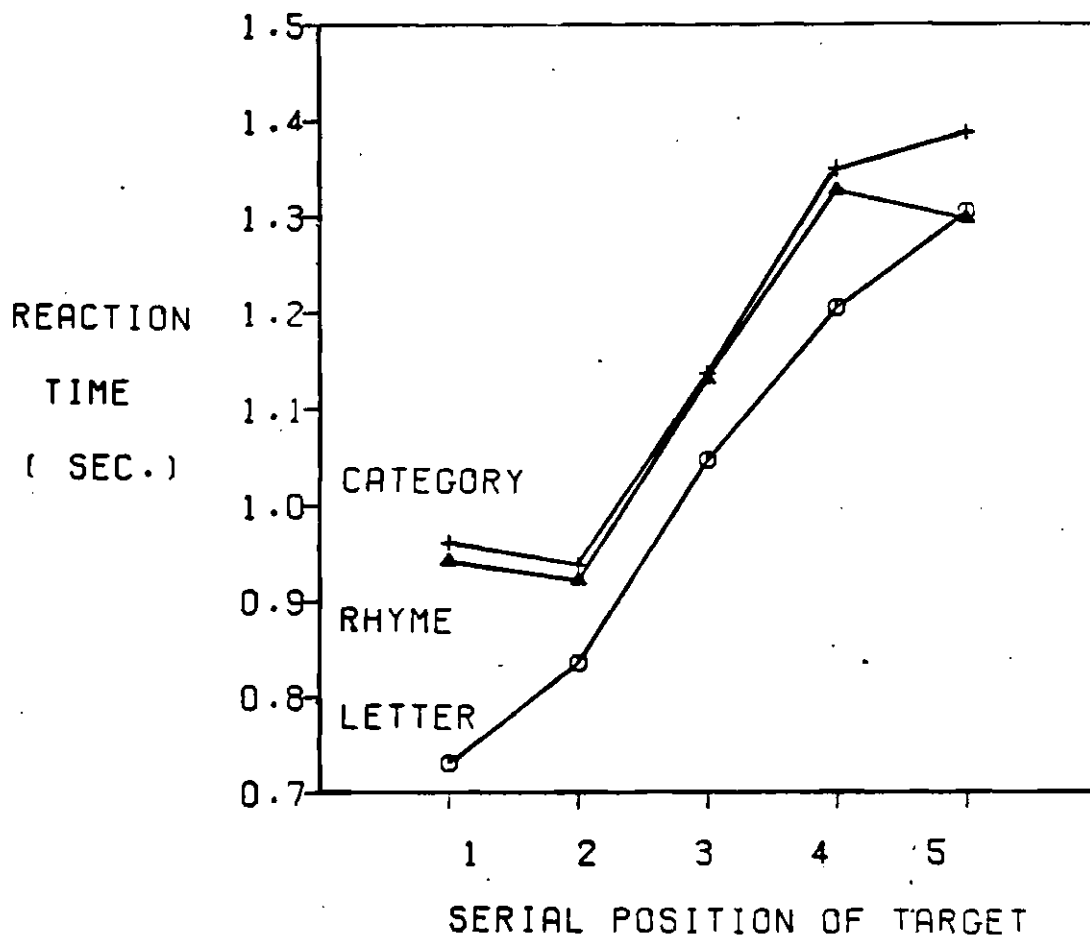


FIGURE 6

REACTION TIME AS A FUNCTION
OF TARGET TYPE AND POSITION
(EXPERIMENT 4)

reaction times for positions two and three and for positions three and four. However, the differences between reaction times for targets in positions one and two, and those in positions four and five were not significant. As can be seen from Figure 6 this effect is primarily due to reaction times for rhyme and category targets. While there was no significant interaction between target type and serial position, this result does suggest that rhyme and category targets were responded to differently than letter targets in this experiment. This result could have occurred if subjects were responding to more than one word at a time. It suggests that responding to letter targets tended to be a word-by-word left to right process as indicated by the linear increase in reaction time at each serial position. Responding to rhyme and category targets, on the other hand, was not linearly related to serial position of the target, but was characterized by a pattern which suggests that response units were larger than single words. Because the interaction between serial position and target type was not significant, the suggestion that responding to letter targets was qualitatively different from responding to rhyme and category targets must be regarded cautiously. However, the difference between the pattern of reaction time for letter targets and that for rhyme and category targets occurred only at positions one and five. Thus, it is not surprising that the interaction was not significant.

CHAPTER 6

EXPERIMENT 5

The suggestion that rhyme and category search differ because rhyme search is word by word while in category search two or more words are handled at a time is not supported by the results of Experiment 4. This leaves the alternate hypothesis that more information about the stimulus word is necessary for rhyme decisions than for category decisions. If this hypothesis is correct then subjects should be able to monitor more words for meaning than for sound in a given period of time. This hypothesis was put to test in Experiment 5. Subjects viewed five stimulus words at a time as in Experiment 4. In this experiment, however, the subjects were required to simply identify the target word after viewing the stimulus for 500 milliseconds. It was hypothesized that subjects should be able to identify the targets more accurately when it was defined semantically than when it was defined acoustically if subjects can monitor more words for meaning than for sound in a given period of time.

Method

Subjects

Subjects were 12 undergraduate students recruited from introductory psychology courses at Georgia Tech. They received class credit for participating in the experiments.

Materials and Apparatus

The stimuli and equipment were the same as those used in Experiment 4.

Procedure

The procedure was similar to that used in Experiment 4 with three exceptions. First, the subjects task was simply to identify the target word instead of to decide whether it was present or not. Secondly, since the subjects task was simply to identify the target, trials in which there were no target items were omitted. Lastly, since the dependent variable was accuracy instead of speed of reaction, it was necessary to limit the exposure duration of the stimulus. Therefore the stimuli were presented for 500 msec. instead of 1 second.

There were two independent variables, clue type and

target position, and both were varied within subjects. The subject initiated each trial by pressing a foot switch. There were eight practice trials before the recorded trials began. The order of clues was random across trials and the clue types were counterbalanced across subjects.

Results

There were eight trials for each combination of target type and serial position. The dependent variable was the number of correct responses, and this was analyzed in an analysis of variance with clue type and target position as within subject variables. The main effect of clue was significant ($F(2,154) = 3.635, p < .05$).

The percentage of correct responses as a function of clue type and serial position of target is presented in Table 3. The percentage of correct responses was 63.8 for letter target, 56.5 for rhyme targets and 65.4 for category targets. Dunn's multiple comparison procedure showed that accuracy was significantly better for category targets than for rhyme targets, but that none of the other pairwise comparisons differed significantly. Thus the hypothesis that subjects should be able to identify category targets more accurately than rhyme targets was supported.

Table 3

Percentage Correct Response as a Function of Target
Type and Serial Position
(Experiment 5)

<u>Position</u>	<u>Target Type</u>			<u>Mean</u>
	<u>Letter</u>	<u>Rhyme</u>	<u>Category</u>	
1	56.3	35.4	49.0	46.9
2	80.2	49.0	66.7	65.3
3	79.2	76.0	90.6	82.0
4	64.6	65.6	68.8	66.3
5	38.5	56.3	52.1	48.8
Mean	63.8	56.5	65.4	61.9

The results show that subjects can monitor more words for meaning than for sound in a given period of time. This suggests that the subject needs to view a given word for a longer period of time in order to make a rhyme decision about the word, than if he is going to make a category decision about the word. A measure of the average amount of time devoted to each word reported accurately was derived for each type of clue on the basis of the data from Experiment 5. First the number of words monitored accurately per trial was determined by multiplying the percentage of correct responses by 5 (the number of words presented on each trial). Subjects were able to monitor 3.19 words correctly when the target was defined in terms of its initial letters 2.83 words when it was a rhyme word, and 3.27 words when the target was defined in terms of a category. The recognition time, that is, the stimulus exposure time necessary per word for the subject to accurately determine the target word, for each target type was determined by dividing the total exposure time by the number of words monitored correctly. These recognition times are presented in Table 4. It can be seen that the difference in recognition time between rhyme and category targets is 24 msec. The average reaction time per word for each target type from Experiment 4 is also presented in Table 4. The decision time per word was determined by subtracting the recognition time from the reaction time.

Table 4

Reaction Time, Recognition Time and Decision Time
as a Function of Target Type

	Reaction Time (Exp. 4)	Recognition Time (Exp. 5)	Decision Time
Letter	205	157	48
Rhyme	225	177	48
Category	231	153	78

This is also presented for each target type in Table 4. It can be seen that the difference in decision time between rhyme and category targets is 30 msec., which is approximately the same as the difference between rhyme and category recognition time but in the opposite direction.

It is also interesting that recognition time for letter and category targets are approximately equal. This may imply that the amount of information necessary to make a letter decision is about the same as that needed to make a category decision. This is consistent with the finding that the most informative parts of a word are the initial and last parts.

In addition, there was a significant effect of target position ($F(4,154) = 19.837, p < .01$). In general, targets toward the middle were identified more accurately than targets at either end. The percentage of correct responses for each serial percentage in order were 46.9, 65.3, 82.0, 66.3, and 49.0. The interaction between clue type and target position was also significant ($F(8,154) = 3.148, p < .05$). As can be seen from Table 3 accuracy was highest when targets were in the middle except when the targets were defined in terms of their first two letters. In this case, accuracy was highest when the target was in position one. Thus, for letter targets accuracy was higher when the target

was toward the left of the visual field. This again suggests the tendency for subjects to precede in a word by word manner for letter targets, while adopting a different strategy for rhyme and category targets, as noted in Experiment 4.

CHAPTER 7

DISCUSSION

This series of experiments was conducted to determine why search for target words defined in terms of semantic features is faster than search for targets defined in terms of sound or visual features. In Experiment 1 category decision time was longer than rhyme decision time, which was longer than letter decision time. This result replicates the findings of Cohen (1968) and those of Craik and Tulving (1975) that reaction time to semantic features is slower than reaction time to acoustic or visual features. As the subjects response was identical to that used in the search task, the results also show that faster semantic search is not due to the particular type of response required in the search task.

In Experiment 2 when subjects searched through paragraphs, search for targets defined semantically was faster than search for targets defined acoustically or visually when the subject searched through paragraphs. This occurred both when the word order of the paragraphs was normal, and when it was scrambled so that the paragraph was no longer meaningful. Analysis of median search speeds showed a small improvement in search time with normal word

order, but only for category targets. This difference suggests that context might account in part for faster semantic search. This effect is relatively small, however, because category search was faster than rhyme or letter search even with the scrambled word order. Context effects were also indicated by the finding that search speeds for rhyme and category targets increased as the subject proceeded further along in the paragraph. This suggests that subjects might be able to use information from the words searched in the initial part of the paragraph to infer which words might occur later in the passage. This notion is consistent with the account of reading outlined earlier, which suggests that readers make hypotheses about the meaning of a passage and use these hypotheses as they proceed through the passage. The results of Experiment 2 suggest that readers can do this with a minimum number of contextual clues, and that merely scanning the words of the passage allows one to guess which words are coming up later. This notion seems especially plausible when subjects are searching on the basis of a semantic feature clue. It is not completely clear why this effect should occur when the target is defined in terms of an acoustic feature. Perhaps when subjects search for an acoustic feature in a paragraph they also attend to the meaning of the words to some extent. When the subjects search for a physical feature (i.e. letters) this guessing strategy cannot be used to facilitate search.

The results of Experiment 3 indicate that context does not account entirely for the faster semantic search found in Experiment 2. In Experiment 3, context was eliminated by having subjects search through random lists of words arranged in paragraphs order. If context could account entirely for faster semantic search, semantically defined targets should be found more slowly than acoustically defined targets when context is eliminated. Unlike the results of Experiment 1 where a category decision time was slowest, and those of Experiment 2, where category targets were found fastest, in Experiment 3, search times for rhyme and category targets did not differ. Thus in the absence of context, semantic and acoustic search speeds were equivalent, while search for visual features was fastest.

These results of experiments 2 and 3 raise some new questions. First why is it that semantic targets are found faster than visual targets in paragraphs but not in random word lists. There are at least those factors that make paragraphs different from the random lists used in Experiment 3. One is word order, which was altered in Experiment 2 with no resulting effect. Another is semantic redundancy, that is, the presence of certain words in the paragraph leads one to expect certain other words to occur later in the paragraph. The internal interrelationship of

the meanings of the words leads to faster search time. This was discussed earlier in terms of the results of Experiment 2. A third difference is the presence of function words in paragraphs. Function words are words which carry few unique semantic features and which have a high probability of occurrence. These are often articles, conjunctions and prepositions. Paragraphs contain many of these, while the random lists of Experiment 3 contained none. It could be that in searching paragraphs for semantic targets, subjects could safely ignore function words, while in searching for visual targets they could not. In the random lists all the words had to be scanned since no redundancy was present.

A second interesting point is the lack of a difference between acoustic and semantic search time in Experiment 3. If all redundancy were eliminated, then search time for acoustic targets would be expected to be faster than search time for semantic targets, because semantic decisions are slower than acoustic decisions (Experiment 1; Craik and Tulving, 1975; Cohen, 1968). One possible explanation for such a finding is that subjects attend to words one at a time when they are searching for acoustic features while they can attend to more than one at a time when searching for meaning. Another explanation is that decision time is not the only factor important in

determining speed of reaction in the search task. It may be that the information necessary to make a semantic (categorical) decision can be decoded from the visual stimulus faster than the information necessary to make an acoustic (rhyme) decision. Thus subjects should be able to monitor more words for meaning than for sound in a given period of time.

In Experiment 4 the hypothesis that search for either rhyme or letter targets is a word by word process while category search is not was tested. If reaction time reflects the number of units attended to then differences in the size of response units should be reflected in differences in the relationship between reaction time and target position. If search is a word by word process then reaction time should increase in a linear fashion with serial position of the target. If, on the other hand, response units are larger than a single word then the relationship between reaction time and target position should not be strictly linear. Instead there should be no differences in reaction time for words within a single response unit. In Experiment 4 subjects were presented five words on each trial and they decided whether any of them fit in a given letter, rhyme, or category clue. It was hypothesized that while reaction time for letter and rhyme clues would increase in a linear fashion with serial

position of the target, reaction time for category targets would be characterized by a pattern which reflects larger response units. That is discrete increases in reaction time should not occur between targets at each successive serial position if response units do not consist of single words. The results suggested that there were plateaus in response time; speed of reaction did not differ for targets in the first two serial or last two positions. These results indicate that subjects may have been responding to more than one word at a time when looking for category or rhyme targets. Thus, category and rhyme search do not differ qualitatively in this respect. There seemed to be a linear increase in reaction time for letter targets suggesting that subjects respond in a word by word fashion when searching for physical feature information. These results are only suggestive however, since the interaction between serial position and target type was not significant.

The notion that more information about the stimulus word is necessary for rhyme decisions than for category decisions was tested in Experiment 5. Subjects viewed five stimuli words presented for 500 msec. and tried to identify the target word on the basis of a letter, rhyme, or category clue. Subjects were able to detect category targets more accurately than rhyme targets, and with about the same accuracy as letter targets. In addition accuracy was best

at the middle target position for rhyme and category targets, while for letter targets accuracy was better in the beginning target position. This suggests that when subjects are looking for a rhyme or category target they try to attend to the display as a whole, while for letter targets they tend to proceed in a word-by-word left to right fashion.

Another interesting aspect of the results is that rhyme targets led to more errors in all the experiments. One reason for this might be that the subjects were normal adult readers who attend to meaning and not to sound in verbal material. In addition faster search was not associated with increased errors, and thus subjects did not sacrifice accuracy to obtain faster search speeds when going from rhyme to category search. It is possible that, at least in paragraph search, subjects attend to the meaning of the words when they were searching for a rhyme target, and this additional task caused more errors.

These results support the contention that decision time is not the only factor in determining speed of reaction in the search task. Instead it seems that search may be viewed as a two stage process. In the first stage, the subject views the stimulus and decodes from it the information necessary to make the necessary decisions. In

the second stage, the subject uses this information to decide whether the target is present in this visual fixation. While the second stage is longer for semantic targets the first stage is longer for acoustic targets. That is the information necessary to make a semantic (category) decision can be decoded from the visual stimuli faster than the information necessary to make an acoustic (rhyme) decision.

The results of Experiment 5 also suggest that the difference between recognition times necessary to make rhyme and category decisions is about 24 msec. In the absence of context, it is expected that category decision time should take longer than rhyme decision time and that the difference should offset the difference in recognition time. The estimate of the difference in decision time determined from Experiment 4 was 30 msec. In addition an estimate of rhyme and category decision time was obtained from the data of Experiment 3 in which subjects searched through random lists of words. The estimates obtained were 120 msec. for rhyme decisions and 138 for category decisions. The difference between these is 18 msec. which is fairly close to the estimate of the difference between rhyme and category recognition time obtained from Experiment 5. This supports the contention that longer recognition time for rhyme targets is balanced off by longer decision time for category

targets in the search task. In addition, the difference in rhyme and category reaction time obtained by Craik and Tulving was 22 msec. All of the estimates are reasonably close to the estimate of the difference in recognition time obtained from Experiment 5.

The results of Experiment 5 suggest that subjects always have to decode structural aspects (i.e. physical features) of verbal stimuli before determining sound or semantic features. While this point may seem to be an intuitively obvious one, there are those who suggest that semantic features can be accessed prior to physical feature information (see Ball et al., 1975). The important point here is that the amount of physical feature information necessary varies with the task. More physical feature information is necessary in order to make a rhyme decision than is necessary to make a category decision. The estimate of the additional time necessary to determine the target word for a rhyme clue obtained from Experiment 5 (about 24 msec.) would be about equal to the time necessary to decode one or two unrelated letters (Sperling, 1967). With the constraints of English orthography one piece of information might be represented by more than one letter. However, the additional information necessary to make a rhyme decision probably tends to come from the middle of the word where orthographic constraints are weakest. The estimate of 24

msec. additional time would then imply that about one or two additional pieces of information are necessary for rhyme decisions.

The results support the account of reading outlined earlier in several respects, and also provides some new information. The results indicate that in scanning a line of print subjects do not need to analyze each word or each letter of any particular word. Context allows the reader to make guesses about which words will come up later in the passage. In order to determine the meaning of a particular word the reader need only attend to some part of it and not to each individual letter. In the present experiments, subjects were able to selectively attend to certain parts of the words only when searching for initial letters or category targets. For rhyme targets the subject had to attend to more physical features of the word. It may be that poor readers attend to sound information to a greater extent, which takes longer to decode and hence slow the reading process. While this step is necessary in beginning reading it is not characteristic of advanced reading. Thus the transition from sound to semantic decoding may be a crucial link in the development of reading.

Finally, the results suggest that context is not entirely responsible for the reader's ability to take in

several words in a glance. While Haber (1974) suggests that the limits of visual acuity are such that only one word can be seen clearly in a visual fixation, the present results suggests that subjects can attend to more than one word at a time. This is possible since the subject doesn't need to see the entire word clearly in order to determine what the word is when he is searching for meaning. The results are also consistent with the notion that the ability to use redundancy while reading helps subjects to take in several words at a time.

BIBLIOGRAPHY

- Averback, E. & Coriell, A.A. Short-term memory in vision. Bell System Technical Journal, 1961, 40, 309-328. In M. Coltheart (Ed.) Readings in cognitive psychology. Toronto: Holt, Rinehart and Winston, 1972.
- Ball, F., Wood, C., & Smith, E.E. When are semantic targets detected faster than visual or acoustic ones? Perception and Psychophysics, 1975, 7, 1-8.
- Battig, W. F. & Montague, W. E. Category norms for verbal items in 56 categories: A replication and extension of the Connecticut norms. Journal of Experimental Psychology, 1969, 80, Part 2, 1-46.
- Bruner, J.S., & O'Dowd, D. A note on the informativeness of parts of words. Language and Speech, 1958, 1, 98-101.
- Chapanis, A. The reconstruction of abbreviated printed messages. Journal of Experimental Psychology, 1954, 48, 496-510.
- Cohen, G. A comparison of semantic, acoustic, and visual criteria for matching word pairs. Perception and Psychophysics, 1968, 4, 203-204.
- Cohen, G. Search times for combinations of visual, phonemic and semantic targets in reading prose. Perception and Psychophysics, 1970, 8, 370-372.
- Craik, F.I.M., & Lockhart, R.S. Levels of processing: A framework for memory research. Journal of Verbal Learning and Verbal Behavior, 1972, 11, 671-684.
- Craik, F.I.M., & Tulving, E. Depth of processing and the retention of words in episodic memory. Journal of Experimental Psychology: General, 1975, 104, 268-294.
- Gibson, E.J. The relationship between perceptual development and the acquisition of reading skill. Project No. 90046, U.S. Department of Health, Education, and Welfare, 1971.
- Gibson, E. J., Osser, H., & Pick, A. A study in the development of grapheme-phoneme correspondences. Journal of Verbal Learning and Verbal Behavior, 1963, 2, 142-146.

- Gibson, E. J., Pick, A., Osser, H., & Hammond, M. The role of grapheme-phoneme correspondence in the perception of words. American Journal of Psychology, 1962, 75, 554-570.
- Haber, R.N. Visual Perception. In Shenick, C.E., Haber, R.N., Wickelgren, W.A., Supper, P., Lenneberg, E.H., Long, B.S., Douglas, V.I., Baldwin, C.P., Baldwin, A.L., Swets, J.A., & Elliot, L.L. (Eds.) Psychology and the handicapped child. U.S. Government Printing Office: Washington, 1974.
- Haslerud, G.M., & Clark, R.E. On the redintegrative perception of words. American Journal of Psychology, 1957, 70, 97-101.
- Horowitz, L.M., White, M.A., & Atwood, D.W. Word fragments as aids to recall the organization of a word. Journal of Experimental Psychology, 1968, 76, 219-226.
- Hunt, K. P., & Hodge, M. H. Category-item frequency and category-name meaningfulness (m'): Taxonomic norms for 84 categories. Psychonomic Science Monograph Supplements, 1971, 4, No. 6 (Whole No. 54), 1971.
- Kellas, G., & Butterfield, E.C. The interaction of pronunciability and response pretraining on the paired-associate performance of third-grade children. Journal of Experimental Child Psychology, 1970, 9, 265-271.
- Kirk, R. E. Experimental design: Procedures for the behavioral sciences. Belmont, Cal.: Brooks-Cole, 1968.
- Krueger, L.E. Search time in a redundant visual display. Journal of Experimental Psychology, 1970, 83, 391-399.
- Krueger, L.E., Keen, R.H., & Rublevich, B. Letter search through words and nonwords by adults and fourth-grade children. Journal of Experimental Psychology, 1974, 102, 845-849.
- Laycock, F. Flexibility in reading rate and Einstellung. Perceptual and Motor Skills, 1958, 8, 123-129.

- Levin, H., & Kaplan, E.L. Listening, reading, and grammatical structure. In D.L. Horton & J.J. Jenkins (Eds.), The perception of language. Columbus, Ohio: Merrill, 1971.
- Lott, D., & Smith, F. Knowledge of intraword redundancy by beginning readers. Psychonomic Science, 1970, 19, 343-344.
- Merikle, P.M. Presentation rate and order of approximation to English as determinants of short-term memory. Canadian Journal of Psychology, 1969, 23, 196-202.
- Mewhort, D.J.K., Merikle, P.M., & Bryden, M.P. On the transfer from iconic to short-term memory. Canadian Journal of Psychology, 1969, 81, 89-94.
- Miller, G.A. Free recall of redundant strings of letters. Journal of Experimental Psychology, 1958, 56, 485-491.
- Miller, G.A., Bruner, J.S., & Postman, L. Familiarity of letter sequences and tachistoscopic recognition. Journal of General Psychology, 1954, 50, 129-139.
- Miller, G.A., Newman, E.B., & Friedman, E.A. Length-frequency statistics for written English. Information and Control, 1958, 1, 379-389.
- Neisser, U. Decision time without reaction time: Experiments in visual scanning. American Journal of Psychology, 1963, 76, 376-385.
- Neisser, U., & Beller, H.K. Searching through word lists. British Journal of Psychology, 1965, 56, 349-358.
- Neisser, U., & Lazar, R. Searching for novel targets. Perceptual and Motor Skills, 1964, 19, 427-432.
- Neisser, U., Novick, R., & Lazar, R. Searching for ten targets simultaneously. Perceptual and Motor Skills, 1963, 17, 955-961.
- Neisser, U., & Stoper, A. Redirecting the search process. British Journal of Psychology, 1965, 56, 359-368.
- Newman, E.B., & Gerstman, L.S. A new method for analyzing printed English. Journal of Experimental Psychology, 1952, 44, 114-125.

- Posner, M.I., Boies, S.J., Eichelman, W.H., & Taylor, R.L. Retention of visual and name codes of single letters. Journal of Experimental Psychology, 1969, 79, 1-16.
- Posner, M.I., & Peele, S.W. Decay of visual information from a single letter. Science, 1967, 158, 137-139.
- Posner, M.I., & Mitchell, R.F. Chronometric analysis of classification. Psychological Review, 1967, 74, 392-409.
- Posner, M.I., & Taylor, F.I. Subtractive method applied to separation of visual and name components of multiletter arrays. Acta Psychologica, 1969, 30, 104-114.
- Redfield, B. Capricorn Rhyming Dictionary. G. P. Putnam's: New York, 1965.
- Reicher, G.M. Perceptual recognition as a function of meaningfulness of stimulus material. Journal of Experimental Psychology, 1969, 81, 275-280.
- Rubino, C.A., & Minden, H.A. An analysis of eye-movements in children with a reading disability. Cortex, 1973, 9, 217-220.
- Smith, F. The use of featural dependencies across letters in the visual identification of words. Journal of Verbal Learning and Verbal Behavior, 1969, 8, 215-218.
- Spence, J. T., Cotton, J. W., Underwood, B. J., & Duncan, C. P. Elementary statistics. Prentice-Hall, Englewood Cliffs, N. J., 1976.
- Sperling, G. A model for visual memory tasks. Human Factors, 1963, 5, 19-31.
- Sperling, G. The information available in brief visual presentation. Psychological Monographs, 1960, 74, whole #498.
- Sperling, G. Successive approximation to a model for short-term memory. Acta Psychologica, 1967, 27, 285-292.
- Tinker, M.A. Recent studies of eye movements in reading. Psychological Bulletin, 1958, 55, 215-231.

- Thompson, M. C., & Massaro, D. W. Visual information and redundancy in reading. Journal of Experimental Psychology, 1973, 98, 49-54.
- Tuinman, G.J., & Gray, G. The effect of reducing the redundancy of written messages by deletion of function words. Journal of Psychology, 1972, 82, 299-306.
- Venesky, R.L. English orthography: Its graphical structure and its relation to sound. Reading Research Quarterly, 1967, 2, 75-105.

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Academic History:

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Louisiana State University in New Orleans (Now University of New Orleans)	Psychology	B.A.	May 29, 1970
Georgia Institute of Technology	General- Experimental Psychology	M.S.	December 7, 1974
Georgia Institute of Technology	General- Experimental Psychology	Ph.D.	July, 1977

Master's Thesis: Reversal Nonreversal Shift Performance in
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Ph.D. Thesis: The Role of Visual, Acoustic, and Semantic Encoding
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Professional Experience:

1/77 to Present Working on project evaluating freshman admission
procedures at Georgia Institute of Technology. The project is con-
cerned with evaluating the multiple regression equations used to deter-
mine which applicants are accepted for admission. Responsible for
conducting data analysis using institute computer facilities.
(Supervisor: Sam C. Webb)

9/76 to 3/77 Graduate Teaching Assistant, School of Psychology,
Georgia Institute of Technology. Responsibility for organization and
conduct of undergraduate and graduate laboratory courses in experimental
psychology. (Supervisors: M. C. Payne and A. D. Smith)

Professional Experience - Continued

2/77 - 3/77 Interviewer for research project conducted by American Institute for Research. The project is directed by Dr. John C. Flanagan, and is concerned with identifying opportunities for improving the quality of life of older age groups. Had full responsibility for identifying participants for the study (men and women between 48-52 years old and between 68-72 years old), conducting four 3 1/2 hour interviews and submitting a written report to AIR. The project is supported by The Administration on Aging, Department of Health, Education, and Welfare.

9/74 - 9/76 Graduate Research Assistant, School of Psychology, Georgia Institute of Technology. Participated in research project investigating the relationship between perceptual deficit and reading disability. The project was supported by the Spencer Foundation. The primary aim of the project was to determine the relationship between reading disability and the ability to integrate information from different sensory modalities, specifically vision, audition, and touch. Subjects were children in grades 3 through 6. The ability to integrate information from different sensory modalities in adult subjects was also investigated. Participated in contacting officials of the Atlanta Public School System, and had responsibility for contacting personnel at the individual schools in order to obtain subjects. Worked directly with children in several schools of the Atlanta Public School System. Responsibilities also included participation in design of experiments, data collection and analysis, and participation in writing the final report and articles for publication. (Supervisors: Dr. M. C. Payne and Dr. R. K. Davenport)

Summer 1975 and 1976 Research Assistant, School of Psychology, Georgia Institute of Technology. Participated in research project investigating the interaction of human aging and memory. This project is supported by the National Institute of Health. Studies of retrieval difficulties and semantic encoding in different age groups were conducted with the cooperation of community organizations whose members served as subjects. Had responsibility for contacting adult community organizations and arranging to meet with them in order to conduct experiments concerned with retrieval difficulties in the elderly. Also helped to design and implement studies of semantic memory in various age groups. (Supervisor: Dr. A. D. Smith)

9/72 - 9/74 Research Assistant, Yerkes Regional Primate Research Center. Participated in project investigating cognitive-perceptual abilities in non-human primates. The aim of the project was to demonstrate cross-modal perception in non-human primate species. Worked directly with several species of primates at the center, including chimpanzees, orangutans, gorillas, African green monkeys, rhesus monkeys, and woolly monkeys. In addition, had contact with workers on many other projects in the center. Became very familiar with center facilities and operation. Also gathered data for master's thesis, an investigation of concept formation performance in chimpanzees. The project was funded by the National Science Foundation. (Supervisor: Dr. R. K. Davenport)

Papers and Presentations:

Domangue, J. C. Reversal Nonreversal Shift Performance in Chimpanzees. Thesis submitted in partial fulfillment of the requirements for the M.S. degree, Georgia Institute of Technology, December, 1974. Paper presented at the Annual Meeting of the Southeastern Psychological Association, Atlanta, Georgia, Spring, 1975. Submitted for publication.

Domangue, J. C., Soroka, R. D., Payne, M. C., and Davenport, R. K. Oral vs. Written Presentation of Vocabulary Test Items with Poor Readers. Paper presented at the Southern Society for Philosophy and Psychology, Atlanta, Georgia, Spring, 1976.

Domangue, J. C. The Effect of Context on Detection of Semantic and Acoustic Targets in Visual Search. Paper presented at the Annual Meeting of the Southeastern Psychological Association, Hollywood, Florida, Spring, 1977.

Payne, M. C., Jr., Davenport, R. K., Domangue, J. C., and Soroka, R. D. Cross-Modal and Intra-Modal Comparison of Temporally Organized Stimuli. Paper presented at the Annual Meeting of the American Psychological Association, Washington, D.C., Summer, 1976. Submitted for publication.

Payne, M. C., Jr., Davenport, R. K., Domangue, J. C., and Soroka, R. D. Reading Difficulty and Cross-Modal Perception. Final report to the Spencer Foundation, September 30, 1976.

Payne, M. C., Jr., Davenport, R. K., Domangue, J. C., and Soroka, R. D. Temporal Patterns: Modality of Presentation and Reading Retardation. Submitted for publication.

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